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# Quaternary Geology of the St. Marys Area Southern Ontario

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P. F. Karrow

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## GEOLOGICAL MAP

**(back pocket)**

Map 2366 (coloured)–Quaternary Geology of the St. Marys Area
Scale 1:50,000

## ABSTRACT

Devonian limestone underlies the area with drift thickness generally near 100 feet (30 m). An area of sinkholes occurs in the northwestern corner, and outcrops occur near St. Marys.

The area is one of low relief and includes parts of the Milverton, Mitchell, Dublin, Lucan. Seaforth, and Centralia end moraines. Several eskers occur, mainly in the western part. All glacial deposits owe their origin to the action of the Huron and/or Georgian Bay ice lobes.


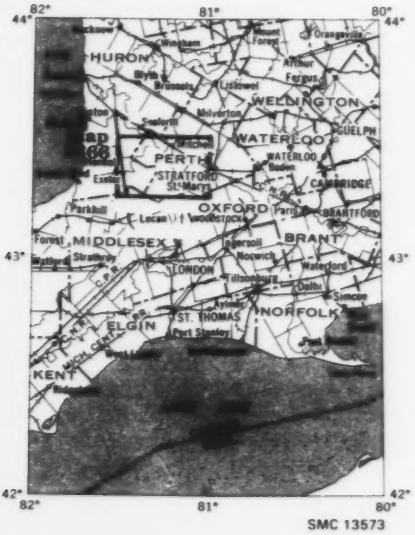


**Figure 1–Key map showing location of St. Marys area. Scale 1 inch to 50 miles (1:3,168,000).**

The unconsolidated rocks are all of Wisconsinan age. Borings have revealed the presence of till under fossiliferous sediments believed to be of Early to Middle Wisconsinan age. Late Wisconsinan deposits consist of the sandy Catfish Creek Till (Nissouri Stade), fossiliferous Wildwood Silts (Erie Interstade), silty Tavistock Till, sandy Stratford Till, clayey Wartburg Till, silty Elma Till, and silty to clayey Rannoch Till (all Port Bruce Stade). Glaciolacustrine silts are widespread at the surface. Glaciofluvial kames and outwash are most abundant at Staffa, Kirkton, and St. Marys, but reserves and production of gravel are very modest.

# Quaternary Geology

of the

# St. Marys Area

# Southern Ontario

by

P. F. Karrow[1]

## INTRODUCTION

### Location and Access

The St. Marys area is located north of London in southwestern Ontario (Figure 1). It extends from Longitude 81° to 81° 30′ west and from Latitude 43° 15′ to 43° 30′ north. National Topographic Series sheet 40P/6 (St. Mary's) shows the area at a scale of 1:50,000; only the east half of the area is available in 1:25,000 scale maps (40P/6a, St. Paul's; 40P/6b, St. Marys; 40P/6g, Mtchell; 40P/6h, Sebringville). The western edge of the area is about 10 miles (16 km) east of Lake Huron and the southern edge of the area is about 15 miles (24 km) from the north edge of the city of London. The area includes parts of Perth, Oxford, Middlesex, and Huron Counties.

The area is traversed by Provincial Highways 4, 7, 8, 19, 23, and 83, and is served mainly by lines of Canadian National Railways. A line of Canadian Pacific railway just enters the area at St. Marys. A grid of roads, usually every mile and a quarter (2 km), crosses the area providing generally good access. Seveal county roads are paved.

### Population and Industry

The area is largely rural, but includes the towns of St. Marys (population 4,577, 1971 census), Exeter (3,304), and Mitchell (2,553) and the smaller settlements of Centralia and Hensall. The western edge of Stratford (23,380) is located centrally along the

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eastern margin of the area. Aside from agriculture (large acreages of corn), there are few industries in the area. Farm consolidation has led to the abandonment of many farm buildings. A long-established stone quarrying and cement industry is located just south of the area at St. Marys. Gravel extraction has long been active on a small scale at a few centres such as St. Marys, Staffa, and Kirkton. Brick plants formerly operated at St. Marys, Mitchell, and Dublin.

## Field Work

Most of the area was mapped in the summer of 1973; mapping was completed early in the summer of 1974.

Natural exposures along stream valleys, and man-made exposures in quarries, pits, excavations, and cuts were supplemented by probe or hand auger holes to gain information on the Quaternary deposits exposed in the area. All roads were traversed as well. Boundaries between mapped units were located with the aid of air photos obtained from the Ministry of Natural Resources, Toronto, and the National Air Photo Library, Ottawa. Preliminary maps have previously been issued (Karrow and Apon 1974; Karrow 1974b).

## Acknowledgments

Field assistance in 1973 was provided by F.J. Apon, F. Hutnik, and G.M. Pucovsky. K. King concurrently carried out laboratory analyses of samples collected in the field. A.J. Ferguson assisted with final mapping in 1974.

Additional information on subsurface soils were provided by Mr. T.B. Collings, Engineer for Perth County, Mr. J.W. Britnell, Engineer for Huron County, R.M. Dawson, consulting engineer, B.M. Ross and Associates Limited, M.M. Dillon and Company Limited, Dominion Soil Investigation Limited, Donald Inspection Limited, the Town of St. Marys, the Upper Thames River Conservation Authority, the Ministry of Natural Resources Petroleum Resources Section, the Ontario Ministry of Transportation and Communications, and the Ontario Ministry of Environment. In 1972 and 1974 stratigraphic test holes were drilled near Avonton and Staffa; support for the drilling was provided by National Research Council Grant A5245 to the author.

Pollen identifications were made by Dr. J. Terasmae, then of the Geological Survey of Canada (now Brock University), R.J. Mott, Geological Survey of Canada, and Dr. B.A. Screenivasa, University of Waterloo.

The geological problems of the area have been discussed over a period of several years with Professor A. Dreimanis, University of Western Ontario.

All these sources of information have contributed to the present study and helped to shed light on the geological history of the area, for which the author is very grateful. Access to private land was cheerfully provided on many occasions by the residents of the area.

## Previous Work

Bedrock geology mapping of the St. Marys area was most recently reported on by Caley (1943) and updated on a map by Sanford (1969). Limestones of the St. Marys area were described by Hewitt (1960; 1964). Bedrock topography data for the area were compiled by Karrow (1965).

Regional mapping of glacial end moraines was first accomplished by Taylor (1913) and later extended and refined by Chapman and Putnam (1966). The latter authors delineated the major end moraines, eskers, and spillways (meltwater channels) of the area. Regional study of till variations in southern Ontario by Dreimanis (1961) included some sample sites in the area.

Semi-detailed mapping of Quaternary deposits has been carried out in adjacent sheets to the northeast and east (Karrow 1971) and the stratigraphic nomenclature established there (Karrow 1974a) has been extended into the present map-area. The area to the southeast has been described by Cowan (1975) and the area to the south has been mapped by Sado and Vagners (1975).

Aside from brief reconnaissance excursions into the area by the author, while mapping the Stratford area to the east between 1965 and 1968, little attention had been given to the Quaternary history of the area prior to the present study. Quarry exposures south of St. Mary's were studied by Winder and Dreimanis (1957) and Dreimanis is currently studying those exposures in more detail.

The pedologic soils have been described by Hoffman and Richards (1952), Hoffman *et al.* (1952), and Wicklund and Richards (1961). The small portion of Middlesex County in the area is shown in Soil Survey Report No. 6.

## Topography

Much of the area is of low relief. Only along major streams, such as the North Thames River, Avon River, Trout Creek, Fish Creek, and Flat Creek, and at a few prominent parts of end moraine ridges, does local relief exceed 50 feet (15 m). Within a few miles of St. Marys, dissection has produced local relief approaching 100 feet (30 m). Extensive tracts throughout most of the area involve nearly level to gently undulating terrain with local relief of 10 feet (3 m) or less.

The highest elevation is at 1250 feet (380 m), on the crest of the Milverton Moraine in the northeast corner of the area. The lowest elevation is just under 825 feet (250 m) in the southwest corner of the area, west of Centralia.

## Drainage

The most important stream in the area is the North Thames River, which enters the area north of Mitchell at about 1125 feet (343 m) and leaves the area at St. Marys at 975 feet (297 m); it eventually flows into Lake St. Clair to the southwest. Its course is almost due south directly in front of the Mitchell Moraine, which apparently controlled the river's location as an ice-marginal channel. A series of eastern tributaries trace

approximately the trend of the retreating ice margin in earlier time: These include, from south to north, Trout Creek, Otter Creek, Avon River, Black Creek, and Whirl Creek. These streams have gradients of 15 to 20 feet per mile (2.8 to 3.8 m/km). The southern third of the North Thames valley and the Trout Creek valley are based on limestone bedrock.

West of the North Thames valley the grain of the country is nearly north-south, obviously controlled by ice-marginal drainage trending parallel to the North Thames River and the Mitchell Moraine as the Huron ice lobe retreated westward. Only in their lower reaches do western tributaries (Flat Creek and Fish Creek) trend southeast obliquely across end moraine trends. These streams have low gradients (4 to 5 feet per mile; 0.76 to 0.95 m/km).

The Huron-St. Clair drainage divide follows the Lucan moraine north to Cromarty then swings northeastward to follow the Mitchell Moraine north from Mitchell. The area between Hensall and Mitchell is drained by headwaters of the Bayfield River. The other part draining to Lake Huron includes the headwaters of the Ausable River, which originates in ice-marginal channels in front of the Lucan and Seaforth Moraines.

## PALEOZOIC GEOLOGY

The area is entirely underlain by Devonian carbonate formations. Caley (1943) lumped the entire sequence into the Norfolk Formation, but since then considerable further subdivision has been made. Sanford (1969) shows the area as being underlain by the following formations from east to west, and oldest to youngest: the Amherstburg Formation, brown limestone and dolomite in a small area near Stratford; the Lucas Formation, brown limestone and dolomite east of a line through St. Marys and Dublin; and the Dundee Formation, gray to brown fossiliferous limestone under the remaining western part of the area. These formations dip gently westward into the Michigan Basin.

The best exposures of the Lucas and Dundee are to be seen in the quarries of the St. Mary's Cement Company, just south of the area, where a 50-foot (15 m) face exposes the contact of the two formations. A clay seam and rusty-weathered zone below, at one time, were thought to represent a regolith at the contact (e.g., Hewitt 1960), which is now known to be disconformable. A visit to the quarry by the author in 1958 revealed the presence of two parallel seams of brown clayey sediment a few feet apart. There were wedge-shaped projections of this 'clay' obliquely upward and downward from the horizontal seam along joints. The 'clay' contained some sand and angular fragments of the adjacent rock. In appearance, the infilling sediment resembled that found on the floors of caves, sometimes referred to as 'cave mud', and believed to represent insoluble residue from the solution of carbonate rock. There was also some resemblance to injected till wedges in limestone joints recorded by Deere and Shaffer (1956) in Illinois. A sample of the brown sediment was submitted to J. Terasmae, Geological Survey of Canada, for palynological study. In a letter dated February 17th, 1959, he advised that although pre-Pleistocene spores were numerous, 'because of the presence of pollen identified as that of *Pinus banksiana*, *Pinus strobus*, *Quercus*, *Betula*, Chenopodiaceae and spores of ferns (Polypodiaceae) and *Lycopodium* the deposit is certainly Pleistocene in age.' It was therefore concluded that the brown clay seam did not represent a Devonian regolith, but instead probably was washed in by seeping water along solution widened joints and bedding planes and/or high injection forces during glacial overriding.

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**Photo 1–Devonian limestone outcrops, North Thames River at St. Marys.**

ODM9536

**Photo 2–Devonian limestone outcrop, North Thames River, south of Avon River mouth.**

## St. Marys Area

Aside from the quarries, the Dundee Formaton is also exposed in several low outcrops along the North Thames River from Motherwell southward (Photos 1 and 2) and occurs at the valley floor of Trout Creek. A previously unreported outcrop was discovered in the bed of the Ausable River one mile (1.6 km) west of Cromarty. Borings for a new bridge across the river two miles (3.2 km) southwest of Cromarty also encountered limestone at the level of the creek bed.

# QUATERNARY GEOLOGY

## Geomorphology

### BEDROCK TOPOGRAPHY AND DRIFT THICKNESS

Bedrock elevation data have been compiled from available water, oil, and gas wells and engineering borings (Karrow and Ferguson 1974). Interpretation of this data suggests that the bedrock surface has a general slope from 1100 feet (336 m) elevation in the northeast to 750 feet (228 m) in the southwest.

A few notable buried valleys have been recognized. The deepest crosses the northwest corner of the area, north of Hensall and, with a depth approaching 300 feet (91 m), reaches basal elevations below 700 feet (213 m). This valley is believed to continue northeast toward Seaforth and westward to Lake Huron.

A valley about 50 to 100 feet (15 to 30 m) deep trends north from Rannoch to Mount Pleasant then northeastward to Mitchell. It appears to join another valley extending eastward from Exeter to near Mount Pleasant. The latter is about 150 feet (46 m) deep at its maximum northwest of Kirkton. Uncorrelated lows occur west of Mitchell; other valleys may therefore exist there.

By and large, present major streams do not correspond to bedrock valleys, presumably because of the drainage disruption caused by glaciation. The Rannach-Mitchell valley probably represents an ancestral course of the North Thames River; for part of its extent it is followed by Flat Creek.

Drift thickness varies from over 300 feet (91 m) over the bedrock valley north of Hensall to zero at bedrock outcrops already described. Substantial areas of shallow drift, less than 50 feet (15 m), occur near Cromarty, but through most of the area it is about 100 feet (30 m) to bedrock from the surface. Over bedrock valleys north of Kirkton and near Mount Pleasant depths of drift of up to 200 feet (60 m) occur.

### KARST FEATURES

Two areas of sinkholes occur west of Cromarty. One area, containing over 15 sinkholes, occurs in an area of shallow drift in front of the Lucan Moraine (Photo 3). The other, with about 10 sinkholes, occurs in another area of shallow drift in front of the Seaforth Moraine. A few additional sinkholes have been found to the west in the northeast corner of the Grand Bend map-area (A.J. Cooper, personal communication) and similar features could occur to the north in the Seaforth area.

ODM9537

**Photo 3–Air photo of sinkhole locations west of Cromarty.**

ODM9538

**Photo 4–Sinkhole, one mile (1.6 km) northwest of Cromarty.**

Most of the sinkholes are less than 15 feet (4.6 m) deep and 30 feet (9.2 m) in diameter (Photo 4). Some have open holes in the bottom up to 18 inches in diameter capable of carrying substantial flows of water; in some sinkholes several such openings can be seen. Many sinkholes have closed bottoms and retain pools of water for varying lengths of time as seepage slowly drains them. It is evident that their drainage condition changes from time to time, with periods of open flow alternating with periods of blockage. During times of blockage, pond sediments (silt and clay with organic matter) accumulate in them; the sediments are later cut through and exposed to varying degrees in the slopes of the sinkholes.

The deepest sinkhole is located in the western group two and a half miles (4 km) north-northeast of Chiselhurst. It is estimated to be 25 feet (7.6 m) deep and 100 feet (30 m) in diameter (Photo 5) and is indicated by a depression contour on the topographic map.

The largest sinkhole, and the only one exposing bedrock at its margin, is located within the newly-located outcrop in the bed of the Ausable River west of Cromarty. This sinkhole is estimated to be 150 feet (46 m) across and over 400 feet (122 m) long. A rim of limestone outcrop three to four feet (1 m) high nearly encircles the flat

ODM9539

**Photo 5–Sinkhole, two and a half miles (4 km) north-northeast of Chiselhurst.**

meadow on the surface of the sinkhole fill. At times of low water, the Ausable River disappears underground at the upstream (north) edge of the meadow but at times of high water the excess flow continues across the meadow to a reach with a bedrock floor, and on downstream. Nearby areas of bedrock outcrop display slabs of rock tilted in chaotic fashion, suggesting collapse.

All the sinkholes occur in an area underlain by limestone of the Devonian Dundee Formation (Sanford 1969). Because of the general cover of Quaternary sediments averaging about 50 feet (15 m) deep (a test hole within the eastern group encountered bedrock at a depth of 32 feet (9.7 m)) nothing is known about the degree of development of caves, but the number of sinkholes, their size, and their water-carrying capacity, suggest more than solution-widened joints are involved.

## TILL PLAINS

Large areas of nearly level to undulating till plain, part of the Stratford till plain of Chapman and Putnam (1966), occur in the map-area, but much of this has been modi-

fied to varying degrees by lacustrine sedimentation in ponded glacial meltwaters. As the relief on till plains increases, delineation of till and lacustrine areas is easier, but there can be gradation into the hummocky topography of end moraines. Local relief on till plains is usually only five feet (2 m) or so.

The principle areas of till plain can be related to the till sheets which underlie them. The Elma Till plain is confined to the portion of the area north of the Milverton Moraine and east of the Mitchell Moraine. It was formed by the Georgian Bay ice lobe in its latest advance into the area south-southeast to the Milverton Moraine. Scattered areas of lacustrine flats and a few faint ice-marginal trends are the only modifications of the surface. The southern edge of the Elma Till plain is sometimes gradational into the Milverton Moraine.

South of the Milverton Moraine, the slightly older Stratford Till plain extends to the till sheet margin northeast of St. Marys. Lacustrine areas are extensive on this till sheet and become dominant to the south, concealing almost completely the till sheet margin. Often the exposed till plain is marked by broad low ridges apparently marking ice-marginal positions or small end moraines.

A small portion of the Tavistock Till plain occurs in the southeast corner of the area, beyond the Stratford Till margin. Lacustrine areas are present but less prominent than on the Stratford Till sheet. The Tavistock Till plain is deeply dissected by Trout Creek and its tributaries east of St. Marys.

West of the Mitchell Moraine, eastward-moving Huron lobe ice formed several belts of till plain alternating with end moraines trending east of south. Again, lacustrine areas are numerous and in part extensive. South of Cromarty and Fullarton and between the Lucan and Mitchell Moraines, the till plain was dissected, sometimes to depths of more than 25 feet (8 m), by meltwaters flowing generally southeastward.

## FLUTINGS

Along the west edge of the area, from Exeter southward, a number of shallow flutings occur in the till plain. They are not visible in the field but show up clearly on air photos. They indicate the latest ice movement west of the Seaforth Moraine was east-southeast; in general they seem to be associated with the distribution of clay till. The Centralia Moraine seems composed of the same clay till and is assumed to have been formed by this advance. However, flutings occur both in front of and behind the Centralia Moraine.

## END MORAINES

In the southeast corner of the area, large masses of kame sand and gravel underlie the Tavistock Till. They extend northeastward into the Stratford area (Karrow 1971) and southward into the Lucan map-area, apparently marking an overridden kame moraine. This is one of the very few features of the St. Marys area which can be established as palimpsest, since there is a common lack of subsurface information.

A series of low ridges, the Gads Hill moraines (Karrow, in preparation) are believed to mark ice-marginal positions south of the Milverton Moraine. In this area, they trend generally east-west, but to the east in the Stratford area, they curve around to the

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**Photo 6—Milverton Moraine west of Sebringville.**

northeast. In the Stratford map-area, at least many are believed to be palimpsest moraines formed by Tavistock Till with only a thin veneer of Stratford Till. In this area, there is no evidence of the relationship. The ridges are only faintly visible, with the inter-ridge areas usually covered by lacustrine sediments. Some dozen or so fragments of successive ice-marginal positions have been recognized in this area.

The Milverton Moraine (Photo 6), named by Taylor (1913), is a belt of hummocky clay till extending in a gentle arc from the northeast corner of the area to its junction with the Mitchell Moraine at Fullarton. It is generally a low moraine which rises about 25 feet (8 m) above the adjacent till plains on either side. It is relatively prominent where crossed by Highway 8 at Seebach Hill. The clay till comprising the moraine has only been recognized in the moraine itself but is believed to be a Huron lobe till deposited by eastward- or southeastward-moving ice. The north edge of the moraine is sometimes vaguely defined in a hummocky zone of younger, silty Elma Till. The Milverton Moraine clearly truncates the Gads Hill moraines east of Seebach Hill.

A few faint lineations in the Elma Till surface, normal to esker trends on this till, probably indicate ice-marginal positions trending north of east. Such features are more clearly developed on the same till to the northeast in the Conestogo area (Karrow, in preparation).

A major geomorphic boundary is present along the North Thames River valley. To the east, ice movement was southeast, with parallel esker trends, and moraine trends are northeast. To the west, ice movement and associated esker trends are eastward and end moraines trend north-south. This geomorphic unconformity strongly affects the drainage trends and topography of the area.

The Mitchell Moraine (Taylor 1913) is a low belt of hummocky, fine-textured till which arches convexly westward in the north half and convexly eastward in the south

ODM9541

**Photo 7–Seaforth Moraine southeast of Exeter; lake plain in foreground.**

half. It is generally only one half to three quarters of a mile (0.8 to 1.2 km) wide and 25 feet (8 m) high. At its junction with the Milverton Moraine at Fullarton it is more prominent, rising there over 50 feet (15 m), presumably because of its superimposition on top of the Milverton Moraine. The North Thames River valley follows the front of the moraine closely, apparently originating as an ice-marginal drainageway when the ice stood at the Mitchell Moraine. A separate tract of hummocky topography of unknown origin occurs behind the Mitchell Moraine west of Science Hill.

A belt of hummocky till forms a distinct moraine ridge from the north edge of the area to near Russeldale. The extension of this ice-marginal position southward is marked by a meltwater channel along Flat Creek to near Anderson. Although delineated roughly on maps by Chapman and Putnam (1966) and suggested by them to be a continuation of the Lucan Moraine, the present mapping shows it to be parallel to the Lucan Moraine and separate from it. It is about halfway between the Lucan Moraine and the Mitchell Moraine. Because of its prominence west of Dublin, it is here named the Dublin Moraine. About seven miles (11 km) of distinct hummocky ridge up to 50 feet (15 m) high are within the map-area but the length of the northward extension into the Seaforth map-area is as yet unknown. Nor is it known whether any further extension is present to the south in the Lucan map-area.

The Lucan Moraine (Taylor 1913) extends through the area, but in its northern half it is more subdued and narrow. Commonly about 25 feet (8 m) high, it is usually bordered by meltwater channels south of Cromarty, which join to form the Fish Creek valley along the moraine's eastern margin. The moraine is most massive near Kirkton.

The Seaforth Moraine (Photo 7) (Taylor 1913) can be considered as a double moraine belt. South of Highway 83, the western ridge is the more prominent and dis-

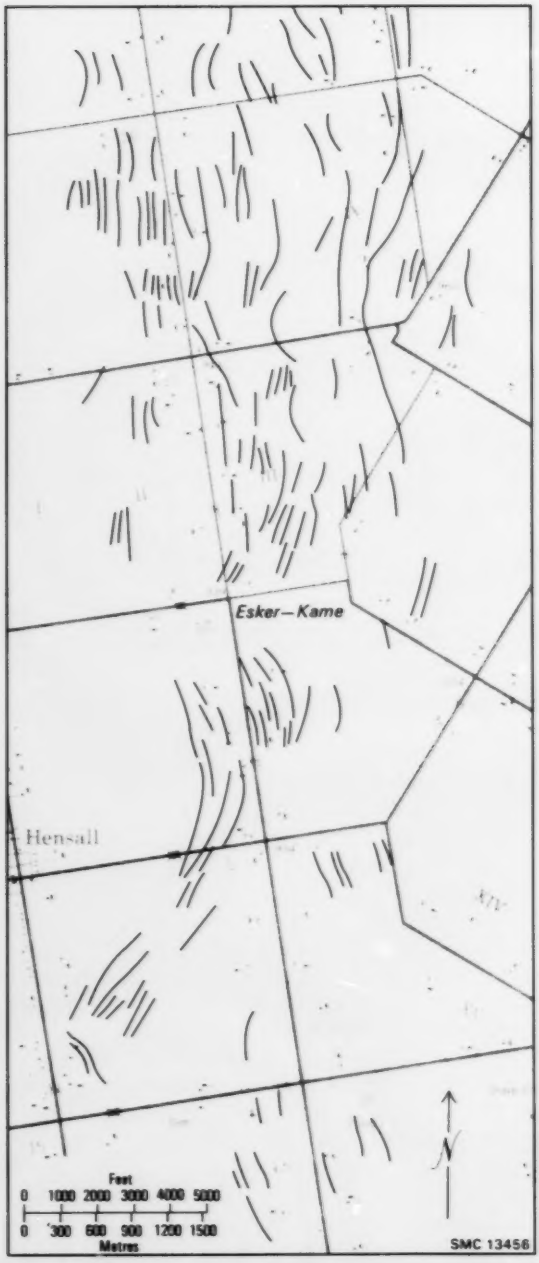


**Figure 2–Pattern of minor moraine ridges on Seaforth Moraine, northeast of Hensall.**

tinct, but to the north the eastern ridge gradually dominates, and becomes the main ridge near Seaforth, north of the area. The moraine reaches a height of 50 feet (15 m) more often than the parallel moraines to the east, but it also is often only 25 feet (8 m) high. It is more sinuous than the moraines to the east, suggesting perhaps thinner ice and greater response to local topography. South of Highway 83, the eastern belt becomes increasingly broader and more diffuse, and the intervening areas become more hummocky, so that separation of the moraine from till plain becomes somewhat arbitrary and subjective. As before, eastern margins (distal) of moraine belts are more distinct and western more gradational. East of Exeter the prominent western ridge has a pronounced eastward convexity; the ridge is breached by the Ausable River there. Between Exeter and Hensall, the western ridge broadens to a belt of closely-spaced low ridges (Figure 2), each probably marking short-duration ice-marginal positions. In this zone, the ice margin apparently retreated more rapidly. Local patches of these small till ridges occur sporadically in both areas delineated as end moraine and as till plain. They may well represent annual accumulations, since the distances between ridge crests are 400 to 500 feet (120 to 150 m), a reasonable amount for annual retreat rates. It has not been possible to map the individual ridges at the present scale of mapping. Figure 2 shows the pattern of ridges for part of the Seaforth Moraine near Hensall.

The westernmost and youngest end moraine is the Centralia Moraine, named after the town of Centralia on its crest (Karrow 1974b). This moraine was delineated but not named by Chapman and Putnam (1966). It is seldom over 25 feet (8 m) high and is less than a half mile (0.8 km) wide. It arches convexly eastward and fades out northward near Exeter. It trends southwest out of the area and appears to have been overridden by the Wyoming Moraine to the west. In this regard it is comparable to the Clinton Moraine, as described by Taylor (1913).

## ESKERS AND KAMES

About a dozen eskers occur in the area; most are west of the Mitchell Moraine. These sinuous to nearly straight ridges of sand and gravel represent subglacial stream bed deposits formed during the last stages of melting stagnant ice. The eskers of the area are small to medium in height (up to 25 feet (8 m)) and only a few miles in length.

The largest esker is the St. Marys Esker, about eight miles (13 km) long, in the southeast corner of the area. It continues southeast a short distance into the Woodstock area (Cowan 1975). It is believed to have formed during the deposition of the Tavistock Till sheet because that till is interbedded with sand and gravel in the flank of the esker, and it extends well beyond the margin of the Stratford Till sheet. Two miles (3.2 km) west of Conroy the esker divides into two branches, with the smaller branch heading south then southeast along the edge of the Trout Creek valley. This short branch probably formed a later path for meltwaters as it has a steeper gradient to lower elevations. Since it is perched on the shoulder of the Trout Creek valley, clearly the valley had not yet been cut. Meltwater flow at the time the esker was formed was southeastward.

A small esker, now almost entirely removed by gravel operations, formerly existed between Sebringville and Stratford. Toward Stratford it grades into a tunnel valley filled to the brim with gravel; it could thus be described as an 'upside-down esker'. Structural

relationships are obscured because the pits are largely below the water table.

Two small eskers occur on the Elma Till plain north of the Milverton Moraine. One, about a mile (1.6 km) long, is three miles (5 km) south of Mitchell; the other, about a mile (1.6 km) of which is in the area, is located in the northeast corner of the area and extends farther north into the Seaforth sheet. Both trend south-southeast, parallel to the flow direction of the Georgian Bay ice lobe.

Four eskers lie between the Mitchell and Dublin Moraines. The longest is the Mitchell Esker, four miles (6.4 km) long; it is paralleled by a shorter esker a mile (1.6 km) to the south. Both trend east-west, perpendicular to the Mitchell Moraine. They terminate in small valleys cut through the Mitchell Moraine just north of Mitchell. An intermittent esker over two miles (3.2 km) long trends eastward at Mount Pleasant. It terminates in a meltwater channel which cuts through the Mitchell Moraine south of Fullarton. Over a mile (1.6 km) to the south a few fragments of esker ridge parallel this one.

Three eskers occur between the Dublin and Lucan Moraines. A short esker forms part of the Staffa kame complex. The Kirkton Esker, three miles (4.8 km) long, extends from Kirkton to Anderson, where it terminates at the Flat Creek meltwater channel. This esker has a complex form similar to the St. Marys Esker, with multiple and very irregular ridges. Perhaps some collapse of the ice roof took place late in its formation, causing the stream to split up. Kettle holes and tunnel valley segments add to the complexity of these eskers. An esker less than two miles (3.2 km) long trends southeast to Metropolitan from the mouth of a meltwater channel crossing the Lucan Moraine. This esker is inset in a probable tunnel valley, which likely represents an earlier phase of erosional meltwater action in the subglacial meltwater tunnel.

Two short but high eskers occur between the Lucan and Seaforth Moraines. Both trend eastward and are predominantly sand. The larger, the Lumley Esker, is about four miles (6.4 km) long. Extensive pits along a township road which bisects the most prominent part of the esker reveal a gradation from gravel in the west to sand in the east. The smaller esker is about two miles (3.2 km) southeast of Hensall. Much of this esker was overridden during the minor readvance to the Seaforth Moraine; a thick layer of till caps the west end of the esker. Sand comprises most of this glaciofluvial deposit.

Although there are several kames in the area, very few are of a size to warrant individual mention. These conical or irregular masses of sand and gravel were deposited at the ice margin and most often occur in or near end moraines.

Without question, the most substantial surface kame deposits are those in the Staffa kame complex. There, a small reentrant in the ice front led to the deposition of at least two major masses of kame gravel with meltwaters forming an outwash fan to the northeast in a reentrant in the Dublin Moraine. The form of the ice margin is clearly indicated by steep ice-contact slopes on the north, west, and south sides. The prominence of this kame complex adds strong support for separate naming of the Dublin Moraine.

Substantial kame sand deposits southwest of Chiselhurst were overridden by the ice advance which formed the Seaforth Moraine and, like the nearby sand esker, bear a cap of till. A deposit of kame gravel similarly underlies the till of the Lucan Moraine a mile (1.6 km) southwest of Kirkton, but its lateral extent is unknown.

Pits in till-capped kame and/or outwash gravels occur at the east edge of the area three miles (5 km) south of Stratford. Their origin is obscure. Reference has already been made to the buried kame deposits in the southeast corner of the area near Wildwood Lake.

## OUTWASH LANDFORMS

The area is only sparsely endowed with outwash sand and gravel. The outwash fan of the Staffa kame complex has already been mentioned. Other bodies of meltwater-deposited sand and gravel were laid down as terraces along meltwater channels and as a deltaic deposit at the north end of a small glacial lake east of Exeter.

Most terrace deposits are of limited extent although some extensions are undoubtedly concealed by lacustrine or outwash silts. Most are associated with the channel complex between the Mitchell and Lucan Moraines and are concentrated near Kirkton. The coarse gravels, up to boulder sizes being common, and the occasional large bar forms on the surface, suggest large and fast-flowing meltwater streams were present. Sometimes outwash masses were concentrated where the containing valley widened, reducing the carrying power of the meltwater stream; a good example is to be found northeast of Science Hill in the Flat Creek valley. Much of the southeastern part of the Town of St. Marys is underlain by an outwash terrace. Later, and 50 feet (15 m) lower in elevation, a lower gravel terrace was formed around the southeast edge of town.

High level gravel terrace remnants flank the Trout Creek valley east of St. Marys. A few small gravel terraces occur at intervals along the Avon River, but are almost totally lacking along the North Thames River. Only south of the Avon River do terraces of limited extent occur along the Thames.

## MELTWATER CHANNELS AND SPILLWAYS

Meltwaters from the retreating glacier were able to cut prominent channels in the till plains and even breach the moraines at several locations. These meltwater channels were all referred to as spillways by Chapman and Putnam (1966). True spillways, which drain lakes or ponds, are rare.

Meltwater channels are commonly cut as ice-marginal drainageways in front of end moraines. After several miles they tend to diverge from the moraine front. Such is the case with the Fish Creek valley, in front of the Lucan Moraine, and the Flat Creek valley, in front of the Dublin Moraine. The North Thames River valley has a similar situation in front of the Mitchell Moraine. While the latter is up to 75 feet (23 m) deep, most often the channels are shallow, deepening to about 50 feet (15 m) where they cut across an end moraine. In plan view, accurate patterns of valleys are common Most channels are a quarter to a third of a mile (0.4 to 0.5 km) wide. Drainage was predominantly southeastward.

The Trout Creek valley (Photo 8) was a major meltwater drainageway. Meltwaters flowed eastward in its early history, as they had when the St. Marys esker was forming, probably flowing to Tavistock to enter the headwaters of the South Thames valley. At what stage drainage achieved its present direction is not known, but may have been about the time ice retreated from the Mitchell Moraine. Events south of the area were probably important in this drainage change.

What are probably true spillways breached the Milverton Moraine north of Sebringville and Carlingford. These mile-long (1.6 km) channels carried locally ponded meltwaters through the moraine southward at low gradient.

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**Photo 8–Trout Creek valley east of St. Marys.**

A late phase of activity in meltwater channels was the deposition of silts. The silted channel floors grade into lake plains underlain by similar silt sediments. The silts are believed to derive from slow-moving meltwaters laden with silt and clay ('glacial milk'), the predominant components of the tills of the area.

## LACUSTRINE PLAINS

Much of the area has been affected to some degree by lacustrine sedimentation, forming numerous small and a few medium-sized lake plains. The lacustrine environment apparently prevailed for only short intervals, since no evidence of shoreline features has been found, and lacustrine sediments are often thin. Most pondings were probably shallow, since relief is generally low, and high barriers are uncommon. The initially low-relief till plains generally became still more subdued in relief as the low areas partly filled with silt and clay.

The most extensive lake plain occurs northeast of St. Marys. The Gads Hill moraines on the Stratford Till plain become more subdued and, eventually, completely submerged southward. This lake plain probably extends southward some distance into the Lucan sheet and, allowing for up to six feet per mile (1.1m/km) of isostatic rebound, is the only possible candidate for correlation with Lake Maumee, the earliest of the major glacial Great Lake stages. Further work to the south is needed to prove or disprove such a relationship. The plain slopes gently southward to an elevation of about 1075 feet (328 m) near St. Marys and appears to be too high to correlate with Lake Maumee.

A small lake plain was formed when the ice stood at the Seaforth Moraine. Headwaters of the Ausable River flowing southward in an ice-marginal position built a delta of gravel and sand over a square mile (2.6 $km^2$) area west of Elimville. The lake plain, at an elevation of about 930 feet (283 m) has an area of about four square miles (10 $km^2$) and serves to set off the main Seaforth Moraine ridge quite clearly (Photo 7). Inflow of outwash at the north end of the lake apparently ceased when the ice retreat allowed the Ausable River to drain westward through a saddle in the Seaforth Moraine.

The lake plain has become drained from the south by the Little Ausable River.

A similar, but still smaller, lake plain borders the front of the Centralia Moraine south of the town, again serving to emphasize the ridge form of the low moraine. This lake plain has an elevation of about 860 feet (262 m).

### FLOODPLAINS

Floodplains related to the development of present streams are uncommon and of very restricted extent in the area. Many streams are underfit, having inherited valleys formed by much larger flows of glacial meltwaters. Much of Fish Creek, Flat Creek, and Trout Creek valleys are in this category. Even the North Thames River, the largest stream in the area, has very limited floodplain development, most notable in its southern reaches near St. Marys. The appearance of a bedrock floor there has probably contributed to floodplain development. Since many streams are near or have their source in this map-area, minimal floodplain development is not surprising.

### WETLANDS

Although deep peatlands are absent in the area, swamps and poorly-drained depressions are widely distributed. Because of the level or gently undulating terrain, extensive ditching and tiling is necessary for farming. Areas east of the Mitchell Moraine, and particularly south of the Milverton Moraine, are prominent in drainage problems, although actual wetlands are limited to a few small patches along the east edge of the area. Other wetlands are most common in the abandoned meltwater channels and lake plains between the Seaforth and Mitchell Moraines. Such areas have often been left wooded.

## Stratigraphy

### GENERAL

The St. Marys area is poorly endowed with sources of stratigraphic information. Scattered road cuts along the walls of the Avon valley, Otter Creek valley, and Trout Creek valley, and a few river bank exposures along the North Thames and Black River, provide the only stratigraphic information, all east of the Mitchell Moraine. West of that, no stratigraphic information is available other than a very few pit exposures of a single till over sand or gravel. Less than a quarter of the area can be considered to have adequate stratigraphic control. As a result, while some till sheet relationships can be demonstrated in several sites, many other relationships are inferred or still unresolved. Knowledge of till stratigraphy in this area has benefited greatly from previous studies to the east (Karrow 1971; 1974a).

The stratigraphic sequence (Table 1) on which the historical interpretation must

**Table 1** TABLE OF FORMATIONS FOR THE ST. MARYS AREA

| Age | Unit | Lithology |
|---|---|---|
| Postglacial[1] | modern alluvium | gravel, sand silt |
| | swamp and bog deposits | peat, muck, marl |
| Late Wisconsinan | | |
| Port Bruce Stadial | | |
| | lacustrine deposits | silt, stony clay |
| | outwash | sand and gravel |
| | Rannoch Till | clayey to silty till |
| | Elma Till | silty till |
| | Wartburg Till | clayey till |
| | Stratford Till | sandy till |
| | Tavistock Till | silty till |
| Erie Interstadial | | |
| | Wildwood Silts | silt |
| Nissouri Stadial | | |
| | Catfish Creek Till | sand stony till |
| Early and Middle Wisconsinan | | |
| | | fossiliferous sand |
| | | silty till |

[1]Postglacial—time since glaciers ceased to affect area directly. For this area, approximately last 13,000 years.

be based, has been built up through the recognition of relatively consistent characteristics of various till sheets. Primary recognition, mainly based on texture, color, and position in sequence vertically and areally, takes place in the field. Laboratory analysis of matrix texture and carbonate content supplement the field data. Pebble counts at some sites and till fabric determinations at a few, provide further data.

The tills of the area, with two exceptions, are silty to clayey in texture; the exceptions are the sandy to silty Catfish Creek Till in the subsurface, and the surface Stratford Till. The geomorphic boundary of the Mitchell Moraine, previously described, also is a significant boundary for till composition. To the east, till pebbles are dominantly limestone with some dolomite, Paleozoic clastics, and Precambrian crystalline rock types; to the west, limestone sharply increases to strong dominance with very few other types of pebbles. This reflects the change in source materials overridden by the ice—dolomite from the northwest, and limestone from the west. The surface till in the west, although generally fine-grained, is often stony where rain-washed (Photo 9); a characteristic often seen is the presence of small shattered boulders of limestone, the shattering believed due to recent frost action after exposure.

A distinctive rock type frequently found in the Stratford and Conestogo map-areas to the east, and associated with a northwesterly source from the Georgian Bay lobe tills, is the Precambrian jasper conglomerate. The source for this rock type is the Bruce Mines area north of Lake Huron. Two varieties of Jasper conglomerate, whose distribution

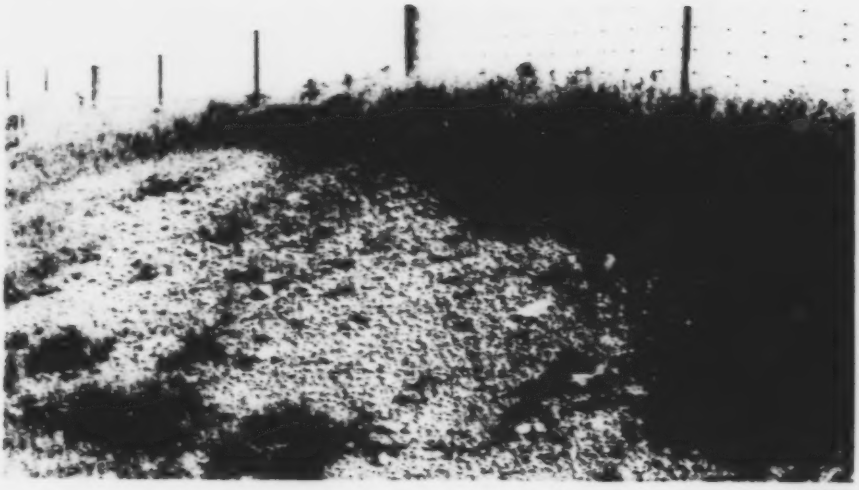

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**Photo 9–Rannoch Till exposure in Lucan Moraine west of Kirkton.**

is shown in Figure 3 have been noted in the St. Marys area. The white or cream variety, the usual type found to the east, was found in only a few sites near the eastern edge of the St. Mary's area. The red variety, also found at only a few sites, occurred only along the Mitchell Moraine and at points to the west. The significance of this distribution is not known.

Discussion of Quaternary stratigraphic units will commence with the relatively well defined sequence south of the Milverton Moraine and east of the North Thames River, and conclude with a summary of the material and relationships in the remainder of the area from oldest (east) to youngest (west). Columnar sections are shown in Figure 4, and detailed descriptions of sections are given in the appendix.

## PRE-CATFISH CREEK SEDIMENTS

The oldest sediments encountered in the St. Marys area were found in borings carried out for stratigraphic investigation on the east bank of the Avon River, one and a half miles (2.4 km) southwest of Avonton (Figure 5). There, below a road cut (referred to as the "Avonton cut") exposing Stratford Till over Tavistock Till, Catfish Creek Till was encountered, in a possible thrust stacking arrangement, interbedded with Tavistock Till or overlying other older tills, in turn overlying fossiliferous silt and sand above sandy silt till. The lowest till is believed to rest on bedrock. The fossiliferous sediments may be correlative with the Port Talbot Interstadial beds near Lake Erie dated as about 45,000 years old (Dreimanis and Karrow 1972); if so the lowest till may be of Early Wisconsinan age.

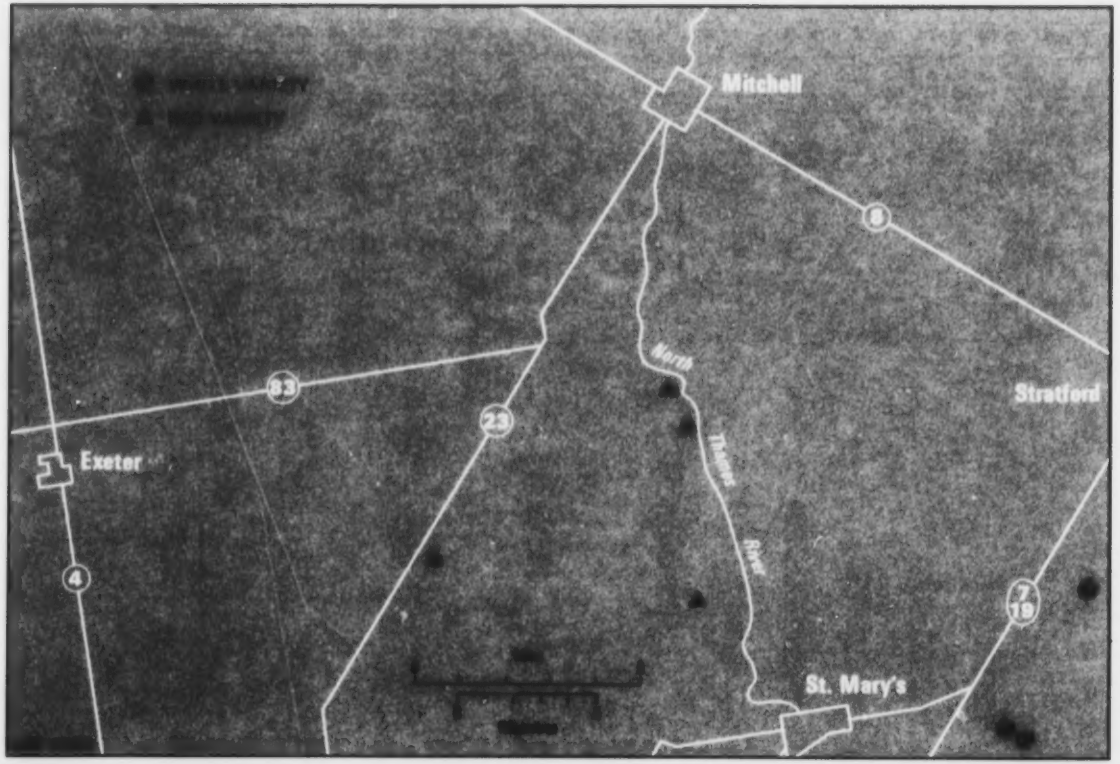


Figure 3–Distribution of jasper conglomerate erratics, St. Marys area.

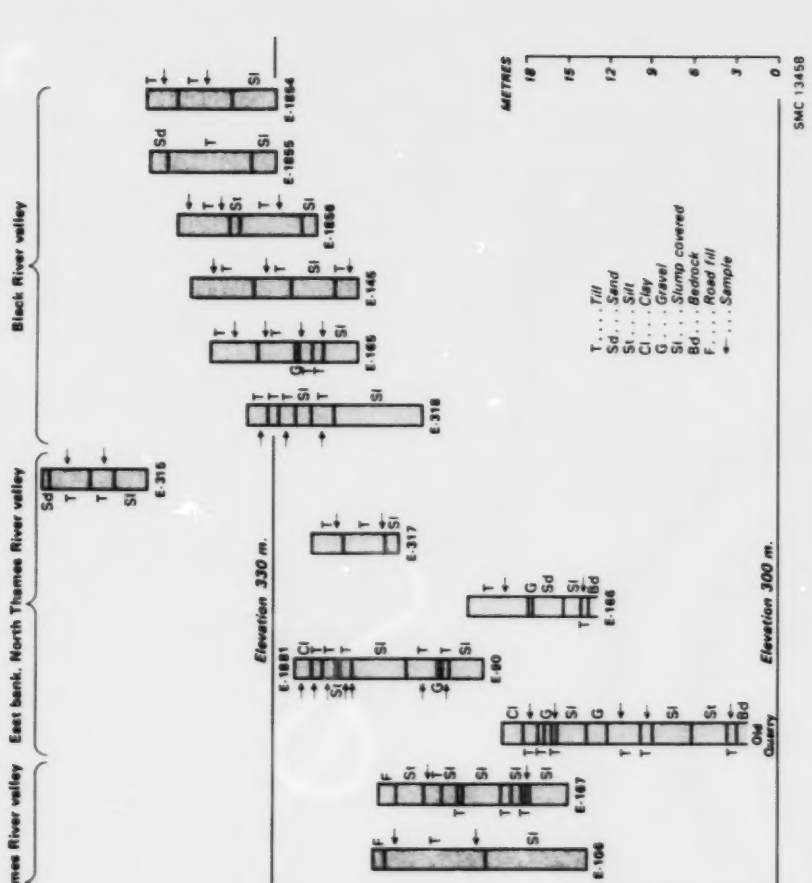


Figure 4–Stratigraphic sections from east and west banks of North Thames River valley and Black River valley, St. Marys area.

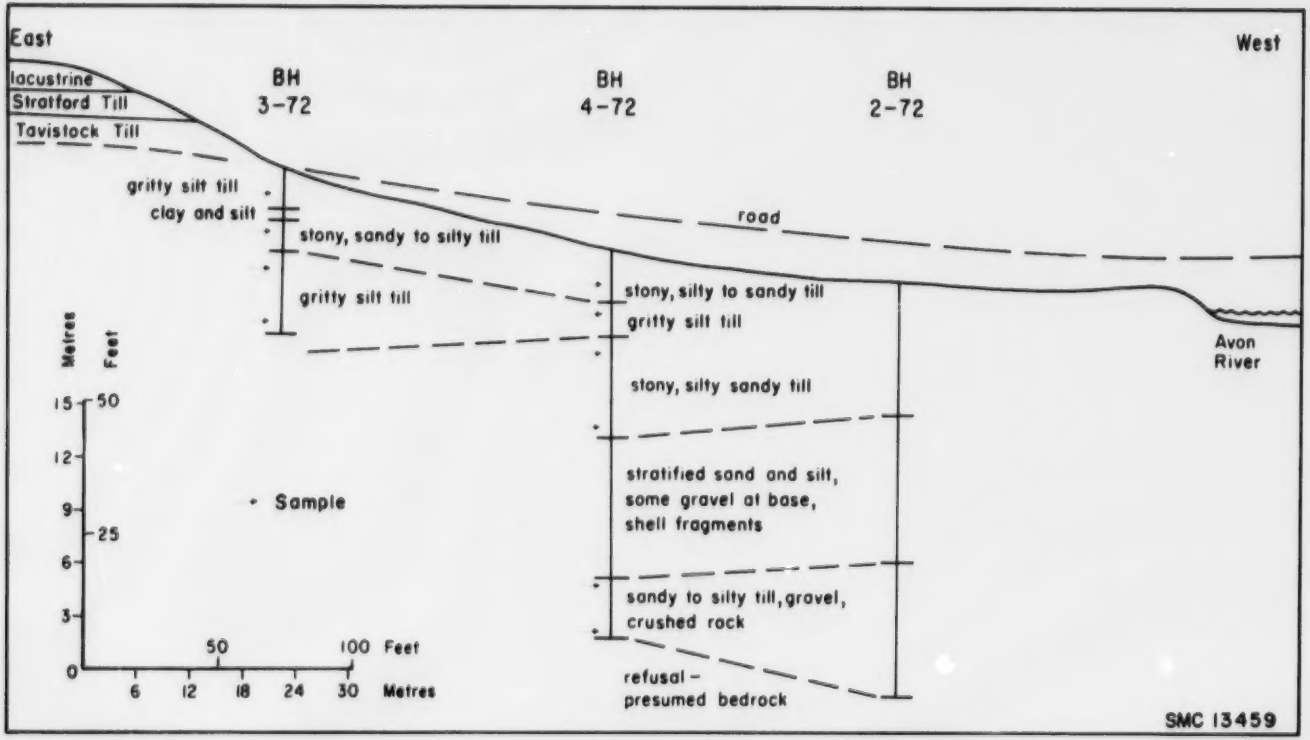


**Figure 5–Geological section at Avonton cut, St. Marys area.**

## St. Marys Area

In the boreholes, the overlying fossilferous sediments contained scattered fragments of mollusc shells, and appeared to contain organic matter as dark laminae. Samples of this sediment were examined by R.J. Mott, Geological Survey of Canada, who reported the pollen assemblages shown in Table 2, with the following comment 'The assemblages, dominated by *Pinus* (pine) and *Picea* (spruce) pollen with minor amounts of other trees, shrubs and herbs, are remarkably consistent among themselves and... are comparable in general to those described for the Mid-Wisconsin Port Talbot and Plum Point Interstadial sediments by Dreimanis *et al.* (1966) and Berti (1971) for buried organic sediments in the St. Davids Gorge (Hobson and Terasmae 1969; Karrow and Terasmae 1970).'

Clay till is exposed below Catfish Creek Till in an exposure in the east bank of Black Creek, three quarters of a mile (1.2 km) above its junction with the North Thames River. Its derivation and stratigraphic significance are unknown.

Exposures at the St. Marys Cement Company old quarry, south of St. Marys, reveal silt till below Catfish Creek Till, resting on bedrock. Thrust stacking here too may be involved (A. Dreimanis, oral communication) but this till may also be older than Catfish Creek Till.

A boring one and a half miles north northwest of Cromarty revealed a thin layer of silt till below Catfish Creek Till and resting on limestone bedrock at a depth of 32 feet (10 m) (see appendix).

## CATFISH CREEK TILL

The most widespread and consistent till unit in southwestern Ontario is the Catfish Creek Till. It forms an important stratigraphic marker through a large area extending from the Grand River valley on the east to the North Thames valley on the west, and from Lake Erie on the south to north of Arthur. It is frequently encountered by well drillers as a hard resistant material often called "hardpan." It is the oldest exposed unit in almost all of the southeast part of the present map-area. It occurs at low elevations in road cuts and stream bank sections along Black Creek, Avon River, Otter Creek, Trout Creek, and the east bank of the North Thames River south of Fullarton. Typically, it is an olive to buff, sometimes gray, stony, sandy to silty till. Tills above the Catfish Creek Till commonly are distinctly finer grained and contrast sharply with it.

Analyses of 16 samples from this area yielded an average of 39 percent sand, 47 percent silt, 14 percent clay, and an average matrix composition of 22 percent calcite, 25 percent dolomite, total carbonate of 47 percent, and a calcite-dolomite ratio of 0.9. Pebble counts on three sites averaged 70 percent limestone, 16 percent dolomite, 2 percent chert, 3 percent clastics, and 9 percent Precambrian rocks. These analyses are summarized and compared with those for other tills of the area in Table 3.

In other areas to the east, the Catfish Creek Till typically has a northeast fabric attributable to regional ice flow during the last glacial maximum, some 18,000 to 20,000 years ago. It has been assigned to the Nissouri Stadial by Dreimanis and Karrow (1972). In the St. Marys area, fabrics at three sites were variable, perhaps because dissimilar levels in the till sheet were analysed. Similar results were reported by Dreimanis (1958) for this till in its type area near Lake Erie, where an early northwest flow was followed by southwest flow and finally northwest flow again out of the Lake Erie basin. This was interpreted to be the result of varying ice thickness and response to the topographic

**Table 2** | POLLEN IN BOREHOLE SAMPLES AT AVONTON CUT.

Percentages based on total grains less aquatics equal to 100.

| Sample No. | 3 | 9 | 10 | 15 | 16 | 19 |
|---|---|---|---|---|---|---|
| Trees Depth | 35.0ft. | 39.5ft. | 40.0ft. | 45.5ft. | 46.0ft. | 50.0ft. |
| *Picea* | 29.2 | 29.0 | 18.5 | 26.7 | 17.0 | 30.8 |
| *Pinus* | 56.7 | 64.0 | 73.1 | 66.4 | 73.6 | 57.3 |
| *Abies* | | | | | 0.9 | 0.9 |
| *Larix* | 0.8 | | | | | |
| *Betula* | 3.3 | | 3.7 | 0.9 | | 0.9 |
| *Quercus* | | | | | 2.8 | |
| *Ulmus* | 1.7 | | 0.9 | | | 0.9 |
| *Carya* | | | | | 0.9 | 0.9 |
| *Fraxinus* | | | | | | + |
| *Tilia* | | | | | | + |
| Shrubs | | | | | | |
| *Alnus* | 2.5 | | 0.9 | | | |
| *Salix'* | | | 0.9 | | | |
| *Myrica* | | | | | | |
| Herbs | | | | | | |
| Gramineae | 8.0 | | | | | |
| Tubuliflorae | 0.8 | 1.0 | | 0.9 | | |
| *Ambrosia* | 0.8 | 1.0 | | 0.9 | | |
| *Artemisia* | | 1.0 | | 0.9 | | |
| Chenopodiineae | | | | 0.9 | | |
| *Sanguisorba* | | | | 0.9 | | |
| Rosaceae | | | | | | + |
| *Rumex* | | | | | | + |
| Ranunculaceae | | | | 0.9 | | |
| Unidentified | | 1.0 | 0.9 | | 1.9 | 0.9 |
| Spores | | | | | | |
| *Selaginella* | | | | | | + |
| *Lycopodium* | | | | 0.9 | 0.9 | |
| *Pteridophyta* | | | | | | 0.9 |
| *Osmunda* | | | | 0.9 | | |
| Polypodiaceae | 3.3 | 3.0 | 0.9 | 2.5 | 0.9 | 4.3 |
| Aquatics | | | | | | |
| Cyperaceae | 10.8 | 3.0 | 2.8 | 0.9 | 2.8 | 1.7 |
| *Typha* | | | 0.9 | | | |
| *Nymphaea* | | 1.0 | | | | |
| *Sphagnum* | 0.8 | 3.0 | 0.9 | 1.7 | 1.9 | 3.4 |
| *Bryophyta* | | | | | | 0.9 |
| Miscellaneous | | | | | | |
| Dinoflagelates | 3.3 | 1.0 | 0.9 | | 2.8 | 0.9 |
| Pre-Pleistocene spores | | | | | 0.9 | |

+—Additional taxa present in samples not counted in detail.

**Table 3** SUMMARY OF ANALYSES ON TILL SAMPLES: AVERAGES AND RANGES.

| | | TEXTURE | | | CARBONATES | | | | PEBBLES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unit | N | Sand | Silt | Clay | Calcite | Dol. | Total | C/D | N | Ls | Dol. | Ch | Clastics | Prec. |
| Catfish Creek Till | 16 | 39<br>22–54 | 47<br>36–60 | 14<br>8–18 | 22<br>19–25 | 25<br>19–30 | 47<br>44–57 | 0.9<br>0.7–1.6 | 3 | 70<br>60–76 | 16<br>11–24 | 2<br>1–3 | 3<br>1–6 | 9<br>7–12 |
| Tavistock Till | 11 | 22<br>10–29 | 49<br>42–56 | 29<br>22–34 | 23<br>20–26 | 18<br>15–21 | 41<br>38–43 | 1.3<br>1.1–1.6 | 3 | 69<br>61–74 | 17<br>16–19 | —<br>0–1 | 6<br>2–14 | 8<br>6–8 |
| Stratford Till | 8 | 39<br>22–54 | 42<br>33–52 | 19<br>9–30 | 26<br>24–28 | 23<br>19–29 | 49<br>45–57 | 1.1<br>1.0–1.3 | 2 | 78<br>73–82 | 11<br>4–18 | 1<br>0–1 | 2<br>1–2 | 8<br>6–11 |
| Wartburg Till | 4 | 10<br>8–13 | 44<br>37–56 | 46<br>34–56 | 24<br>20–28 | 18<br>14–22 | 42<br>35–46 | 1.4<br>1.1–2.0 | 1 | 67 | 15 | 2 | 6 | 10 |
| Elma Till | 8 | 18<br>6–35 | 52<br>41–61 | 30<br>21–40 | 23<br>18–26 | 25<br>21–31 | 48<br>39–54 | 0.9<br>0.7–1.2 | 2 | 68<br>64–72 | 18<br>10–26 | 2<br>0–4 | 7<br>0–15 | 5<br>3–6 |
| Rannoch Till | 40 | 19<br>4–35 | 50<br>39–59 | 31<br>18–47 | 28<br>20–39 | 22<br>12–30 | 50<br>40–61 | 1.1<br>0.9–2.5 | 10 | 91<br>81–95 | 4<br>1–12 | 1<br>0–2 | 1<br>0–8 | 3<br>1–8 |
| (Mitchell) | 19 | 23<br>6–35 | 47<br>39–59 | 30<br>18–44 | 26<br>20–32 | 21<br>17–25 | 47<br>40–57 | 1.2<br>0.9–1.7 | 3 | 86<br>81–94 | 7<br>1–12 | 1<br>0–2 | 1<br>0–4 | 5<br>2–8 |
| (Dublin) | 4 | 20<br>18–22 | 53<br>42–58 | 27<br>23–36 | 27<br>21–28 | 26<br>21–28 | 53<br>42–60 | 1.0<br>1.0–1.1 | 1 | 89 | 2 | — | 8 | 1 |
| (Lucan) | 7 | 15<br>10–26 | 51<br>46–53 | 34<br>19–40 | 29<br>25–31 | 24<br>21–30 | 53<br>49–61 | 1.2<br>0.9–1.5 | 3 | 93<br>92–94 | 3<br>1–4 | —<br>0–1 | —<br>— | 4<br>3–5 |
| (Seaforth) | 6 | 14<br>3–22 | 52<br>49–55 | 34<br>26–47 | 33<br>29–39 | 22<br>12–29 | 55<br>41–60 | 1.7<br>1.1–2.5 | 2 | 93<br>92–94 | 3<br>1–6 | 2<br>1–2 | —<br>— | 2<br>1–3 |
| (Centralia) | 4 | 10<br>4–16 | 52<br>51–55 | 38<br>33–43 | 31<br>25–39 | 20<br>16–24 | 51<br>47–55 | 1.6<br>1.0–2.4 | 1 | 95 | 2 | — | — | 3 |

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**Photo 10–Striae on Devonian limestone, North Thames River (E-166).**

effects of the Great Lakes basins. Many more determinations of till fabric are needed to establish a comparable history of ice movement direction in the St. Marys area. However, striae on the bedrock were observed under Catfish Creek Till at two sites along the North Thames valley (at the new St. Marys Cement quarry, and at station E-166 south of the Avon River mouth (Photo 10)), bearing about 130 degrees and indicating ice movement out of the Lake Huron basin. According to the hypothesis outlined above, this would represent either an early or late phase of ice movement when the ice was thinner.

Although the Catfish Creek Till is known to extend as a sheet under the southeast part of the area, there is little evidence of its presence north of the Milverton Moraine or west of the North Thames River valley. Borings for a dam at Mitchell suggest the possible presence of the till below a surface clay till; a similar relationship is reported at a bridge site on Highway 4, one mile (1.6 km) south of Hensall where 20 feet (6 m) of clay till overlies 15 feet (4.5 m) of sandy till which is probably Catfish Creek Till. Catfish Creek Till was also encountered in a bore hole one and a half miles (2.5 km) north northwest of Cromarty, overlain by less than 10 feet (3 m) of clayey silt till (see Appendix A). Only by drilling will it be found in the balance of the area because of the general lack of stratigraphic information there. Present sketchy data indicate the Catfish Creek Till is simply buried by younger tills, but is not exposed because of the minimal stream dissection of the western part of the area.

## WILDWOOD SILTS

In the southeast corner of the area, near Wildwood Lake, a thick sequence of stratified silts (several tens of feet), often overlain by sand and minor gravel, is inferred to overlie the Catfish Creek Till. These water-laid sediments are covered by the Tavistock Till. Borings for the Wildwood Dam (Figure 6) encountered several feet of silt and clay between tills, which are probably equivalent to the silts outcropping to the southeast. The silts have been named the Wildwood Silts, after the adjacent lake (Karrow and Apon 1974).

The silts clearly represent a thick lacustrine deposit; although overlying sands have been mapped as kame sands, they may be in part lacustrine or deltaic. It seems likely that these lacustrine sediments were deposited in a local lake, perhaps confined to an earlier Trout Creek valley by a dam of glacial materials associated with the Lakeside Moraine. No other thick sequences of fine-grained, water-laid sediments are known from this stratigraphic position, and the Tavistock Till typically overlies the Catfish Creek Till directly, unless another till sheet intervenes.

A textural analysis of the silt revealed it to be 3 percent sand, 81 percent silt, and 16 percent clay (E-176) and to be somewhat more like Catfish Creek Till than Tavistock Till in its carbonate content.

Dr. B.A. Sreenivasa, University of Waterloo, examined a sample of the silt for pollen; the pollen assemblage he found is given in Table 4. Such an abundance of pollen is surprising and suggests interstadial conditions. The interval of ice retreat between deposition of the Catfish Creek Till and Tavistock Till is probably referable to the Erie Interstadial of Dreimanis (Dreimanis and Karrow 1972; Moerner and Dreimanis 1973) and would have an estimated age of about 16,000 years.

**Table 4** POLLEN AND SPORES IN WILDWOOD SILTS

(Counts from three slides)

| | | | |
|---|---|---|---|
| *Picea* | 44 | *Artemesia* | 10 |
| *Pinus* | 170 | *Ambrosia* | 9 |
| *Juniperus* | 7 | Compositae | 8 |
| *Salix* | 4 | *Chenopodium* | 5 |
| *Alnus* | 11 | *Rumex* | 2 |
| *Betula* | 25 | *Nymphaea* | 2 |
| *Ulmus* | 11 | Caryophyllaceae | 1 |
| *Carya* | 9 | Ericaceae | 3 |
| *Quercus* | 10 | Gramineae | 14 |
| *Juglans* | 1 | Cyperaceae | 2 |
| *Tilia* | 2 | *Sphagnum* | 33 |
| *Acer* | 1 | Trilete spore | 2 |
| *Corylus* | 1 | Polypodiaceae | 8 |
| | | *Selaginella* | 1 |
| | | Fern spore | 4 |
| non-arboreal | 28 | *Lycopodium* | 4 |
| pollen | | *Pteridium* | 1 |

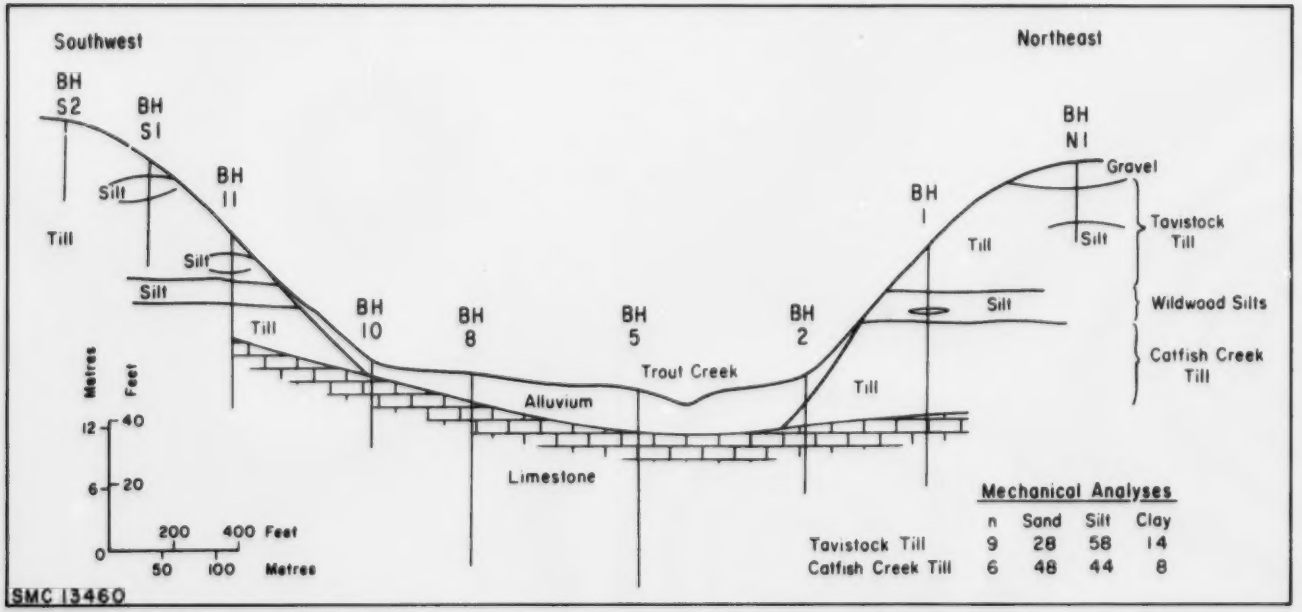



**Figure 6–Geological section at Wildwood Dam, St. Marys area.**

## TAVISTOCK TILL

The Tavistock Till is a gritty, clayey silt till only exposed at the surface in the southeast corner of the area. Its type section is the Harmony cut, south of Stratford and a few miles east of the St. Marys area (Karrow 1974a). It has also been recognized as an intermediate unit in the sequence along the walls of the Trout Creek, Otter Creek, Avon River, and possibly Black Creek valleys. It usually overlies Catfish Creek Till, but in the vicinity of Wildwood Lake it overlies the Wildwood Silts and ice-contact sand and gravel. At the Wildwood Dam it is the surface till (Figure 6), and it is the oldest surface till in the map-area.

Analyses of 11 samples from this area average 22 percent sand, 49 percent silt, and 29 percent clay, 23 percent calcite, 18 percent dolomite, total carbonates of 41 percent and a calcite-dolomite ratio of 1.3. Three pebble counts average 69 percent limestone, 17 percent dolomite, 6 percent clastics, and 8 percent Precambrian. Higher carbonate ratios in both matrix and pebbles occur to the south, presumably because of greater incorporation of limestone bedrock.

Till fabric at two sites indicate a southeasterly ice flow. Mapping in other areas to the east indicate that this is an extensive till sheet, extending south to Woodstock to meet Port Stanley Till deposited by the Erie ice lobe (Cowan 1975). The two tills are believed to be nearly the same age and thus assignable to the Port Bruce Stadial (Dreimanis and Karrow 1972), with an estimated radiocarbon age of about 15,000 years.

To the northeast and back from the outer edge of the Tavistock Till, finer till (Stirton Till; Karrow 1974a) separates it from the Catfish Creek Till below. Fine-grained till of unknown origin occurs along Black Creek near Carlingford with an overlying till resembling Tavistock Till. The fine-grained till could be an equivalent of the Stirton Till, or a different till derived from the west.

## STRATFORD TILL

The youngest till sheet south of the Milverton Moraine is a thin sandy silt till named the Stratford Till (Karrow 1974a). The type section for this till is also the Harmony cut, but a similar cut exposing Stratford Till over Tavistock Till, the Avonton cut (Figure 5), is located one and a half miles (2.4 km) southwest of Avonton in this map-area and serves as a local reference section.

Stratford Till is the surface till through much of the area east of the North Thames River and south of the Milverton Moraine. It forms the surface till in the Gads Hill moraines and can be seen to overlie the Tavistock Till in road cuts along the upper edge of stream valleys such as Trout Creek, Otter, Creek, and the Avon River. The outer margin of the till sheet in this area is concealed by overlying lake deposits but is inferred to trend west to southwest to the vicinity of St. Marys. Because of its general thinness and the subdued relief with overlying lake sediments, the till is not well exposed.

Analyses of eight samples revealed an average composition of 39 percent sand, 42 percent silt, and 19 percent clay, 26 percent calcite, 23 percent dolomite, total carbonate 49 percent and calcite-dolomite ratio of 1.1. Two pebble counts averaged 78 percent limestone, 11 percent dolomite, 2 percent clastics, and 8 percent Precambrian. It is thus very similar to Catfish Creek Till in this area, the Stratford having slightly more clay

and less silt, and in carbonate content the Stratford having a little higher calcite-dolomite ratio. An example of the difficulty in distinguishing the two, which may be cited, is the exposures on the north side of the Avon River at Avonton, where similar till extends without noticeable break the full height of the valley wall. The most reasonable explanation is that the Tavistock Till is missing and Stratford Till directly overlies Catfish Creek Till without a break. A sample from the lower part of the sequence supports this interpretation. Alternative explanations are that a thick mass of Stratford Till is present, or that the Catfish Creek Till extends to the upland surface there. Ice flow direction for the Stratford Till is believed to be southeast, mainly on evidence from till fabrics in the Stratford area (Karrow 1971). It is considered to be of Port Bruce Stadial age.

## WARTBURG TILL

Clay till forms the Milverton Moraine, extending as a belt from a quarter to one mile (0.4 to 1.6 km) wide from the northeast corner of the area to Fullarton, where it was apparently overriden when the Mitchell Moraine was constructed. Because of the truncation of the Gads Hill moraines and general geographical relationships, this clay till is believed to be younger than the Stratford Till, although no exposure has been found where the two tills occur superimposed. To the north, the clay till is overlapped by the next younger Elma Till, and the belt of exposure of the clay till extends only northeast to Brunner, in the Conestogo area (Karrow 1971). Again, from geographical relationships, it is believed to underlie the Elma Till but clear stratigraphic relationships have not been encountered in this area. Clay till in the floor of Whirl Creek at Mitchell may be the same till.

It is proposed to name this till the Wartburg Till, after the village of that name located on the Milverton Moraine. As no stratigraphic relationships can be demonstrated in section, a road cut one mile (1.6 km) southwest of Wartburg is designated as the type section.

Analyses of four samples of Wartburg Till averaged 10 percent sand, 44 percent silt, and 46 percent clay, calcite 24 percent, dolomite 18 percent, total carbonate 42 percent, and calcite-dolomite ratio of 1.4. One pebble count yielded 67 percent limestone, 15 percent dolomite, 2 percent chert, 6 percent clastics, and 10 percent Precambrian.

Because of the limited nature of its exposure, little is known about the origin of this till. It is presumed to have been deposited by the Huron and/or Georgian Bay ice lobes, and to be of Port Bruce Stadial age.

## ELMA TILL

The youngest till east of the Mitchell Moraine is the Elma Till (Karrow 1974a), a predominantly silty till comprising the surface till north of the Milverton Moraine. The outer margin of this till has been mapped northeast through the Stratford, Conestogo, and Palmerston areas (Cowan 1973), and the till sheet is believed to extend northward through the Seaforth area. No exposures have been found which display stratigraphic relationships to other tills in the area but Elma Till is inferred to overlie Wartburg Till

and to have been overridden from the west by the ice advance which formed the Mitchell Moraine.

Analyses of seven samples, identified as Elma Till in this area, average 18 percent sand, 52 percent silt, and 30 percent clay, with the matrix containing an average of 23 percent calcite, 25 dolomite, total carbonate 48 percent and a calcite-dolomite ratio of 0.9. Two pebble counts averaged 68 percent limestone, 18 percent dolomite, 2 percent chert, 7 percent clastics, and 5 percent Precambrian rock types. Previous mapping (Karrow 1971) has shown that this till becomes much more sandy to the north near Listowel. At some sites near its margin along the Milverton Moraine it is more clayey than usual, probably because of incorporation of clayey Wartburg Till; this variation complicates the task of delineating the margin.

Faint ice marginal trends and two small eskers trending perpendicularly are the only sources of information in the area indicating ice movement east of south for this till sheet. Stronger evidence consistent with this, was found in the Conestogo sheet (Karrow, in preparation) and north of Listowel the Teeswater drumlin field indicates a Georgian Bay ice lobe source.

The Elma Till is believed to have been deposited during the Port Bruce Stadial and would have an estimated age of 14,500 years.

## RANNOCH TILL

West of the North Thames River, end moraine alignments and esker trends indicate eastward ice movements from the Huron basin. Five end moraines have been defined in this part of the area (Mitchell, Dublin, Lucan, Seaforth, and Centralia) and some contrasts in till character have been observed to correspond to these ice-marginal positions. However, data to date do not indicate consistent enough differences to justify separate naming of tills for each of these tracts. Also, the almost complete lack of stratigraphic information makes it impossible at present to demonstrate significant ice readvance was involved in the formation of these moraines. Therefore until such time as additional data can be found on which to base a subdivision, all the surface till in the area west of the North Thames River will be lumped under one unit.

The name Rannoch Till is here proposed for this unit, the name taken from a small village along the Mitchell Moraine west of St. Marys. If later subdivision is made, the name Rannoch Till can be retained in a more restricted usage for the till of the Mitchell Moraine, the till plain on its west side, and whatever additional deposits are appropriate. No type section is designated at this time, but road cuts in the Mitchell Moraine near Rannoch can be considered to define a small type area.

Sample analyses listed in the appendix are identified as R (Rannoch Till) with assignment to the various moraines and adjacent till plains on a geographical basis indicated as Rm (Mitchell), Rd (Dublin), Rl (Lucan), Rs (Seaforth), and Rc (Centralia); this arrangement will facilitate comparisons between the till tracts and any future subdivision of the unit which may be attempted.

Rannoch Till (Photo 9), most often a clayey silt till not unlike the Tavistock Till in some exposures, as well as forming the surface till in the Mitchell Moraine and much of the area to the west, probably extends east of the North Thames River in a few places. East of Fullarton and near the mouth of Black Creek, expo-

**Table 5** ORIENTATION OF CLASTS IN BOULDER PAVEMENT AT E-145, BLACK CREEK.

| Clast no. | long axis of clasts | Striae | dip |
|---|---|---|---|
| 1 | 45 | 45 | W |
| 2 | 140 | 35 | – |
| 3 | 150 | 115(1)<br>35(2) | W |
| 4 | 110 | 180 | W |
| 5 | 170 | 160 | W |
| 6 | 40 | 50 | W |
| 7 | 90 | 70 | W |
| 8 | 110 | 95(1?–dominant)<br>150(2?) | W |
| 9 | 95 | 80 | W |
| 10 | 100 | 20 | W |
| 11 | 5 | 60 | W |
| 12 | 40 | 55(1?)<br>130(2?) | W<br>W |
| 13 | 110 | 100 | W |
| 14 | 65 | 65 | W |
| 15 | – | 85 | NW |

sures suggest its presence about a mile east (1.6 km) of the Mitchell Moraine. A borrow pit on the south side of the highway embankment across Black Creek (E-145) formerly exposed a well-developed boulder pavement separating an upper till resembling Rannoch Till from underlying finer till. Striae and the dip and orientation of the cobbles and boulders (Table 5) in this pavement clearly indicated overriding ice derived from the west, assumed to be the Mitchell Moraine advance which deposited the Rannoch Till. The identity of the underlying finer till remains unknown. Rannoch Till has not been identified in a superjacent position on any of the tills previously described. In several exposures, mainly on the west bank of the North Thames River, a coarser upper till, believed to be the Rannoch Till, overlies finer till of unknown origin. A similar sequence is present at the new St. Mary's Cement Company Quarry as well. Similarity between Rannoch Till and Tavistock Till, and even some Elma Till, and Wartburg Till, has made delineating till boundaries in the triangle between Fullarton, Carlingford, and Motherwell particularly difficult; the boundaries presently shown are the best interpretation of the spotty and confusing information now available. More detailed work in that area may require reinterpretation of the till relationships there, but is beyond the scope of the present mapping.

Rannoch Till will be discussed here generally, with some comments on local variations. As with previous tills, averages of sample analyses are given in Table 3.

Texturally, the Rannoch Till becomes finer westward as will be seen by comparing averages for each till tract, with the coarsest textures along the North Thames valley and the finest in the west along the Centralia Moraine. While the Rannoch Till averages overall 19 percent sand, 50 percent silt, and 31 percent clay, in the east sand content ranges over 30 percent and in the west is usually less than 15 percent. Conversely clay content is lower (around 20 percent) in the east and higher (around 40 percent) in the

west. Within the individual till belts, variations are more or less random, with the exceptions that clay content is sometimes greater in the south (a notable feature in the Seaforth tract) and in the Dublin belt composition is particularly uniform. At scattered sites, much coarser till was found at the surface which was interpreted to be ablation till. A graphical comparison of this till with basal till is shown in Figure 7. Patches of ablation till were never extensive enough to be mappable.

In carbonate content, uniformity in the Dublin belt is again striking. Overall the Rannoch Till averages 28 percent calcite, 22 percent dolomite, 50 percent total carbonate and with a calcite/dolomite ratio of 1.1. Higher ratios are evident in the central and southern Seaforth belt and there is an overall weak trend to higher ratios southward.

Pebble counts are rather few but show a trend to higher limestone count to the south and west and lower dolomite count in the same direction. The dominance of limestone is a very striking feature of Rannoch Till, ranging from about 85 percent in the northeast to 95 percent in the southwest. This clearly reflects the effect of local limestone bedrock lithology in overwhelming other rock types carried into the region.

A single till fabric at E-228, near Dublin, indicated ice movement direction at 120 degrees; this is similar to the direction of flutings south of Exeter.

From regional relationships, the Rannoch Till is assigned a late Port Bruce Stadial age, which would make it about 14,000 years old.

## ABLATION DEPOSITS

Ablation deposits include the sand and gravel deposited by glacial meltwater streams either in contact with the ice or at more distant locations away from the ice. Deposits of these types are of limited extent in the area.

Ice contact deposits include kames and eskers. Identification of these deposits was based mainly on their surface form, which typically consists of steep slopes and irregular, hummocky surfaces for kames, and elongate sinuous form for eskers. The constituent sediments vary from well-sorted fine sand to poorly-sorted bouldery gravel. The best exposures in ablation deposits were found in esker pits such as in the Lumley Esker, where large cross-bedding was seen (Photos 11 and 12) which indicated eastward-flowing currents in the depositing stream; the gradation from coarse gravel in the west to fine sand in the east was consistent with this.

The most numerous and extensive ice-contact deposits occur in a belt from Hensall to Staffa, with a large kame complex at the latter locality associated with the reentrant in the Dublin Moraine. Lesser deposits occur near Kirkton and St. Marys. A few sites reveal a till cap on sand and gravel, specifically in the Seaforth Moraine east of Hensall, in the Lucan Moraine west of Kirkton, in the Dublin Moraine west of Dublin, and northeast of St. Marys in the till plain areas of the Stratford Till. Bridge borings at the front of the Seaforth Moraine east of Centralia indicate till over gravel along the Little Ausable River as well. A single exposure east of Science Hill on the west side of the North Thames valley revealed Rannoch Till over sand.

Farther from the ice front, meltwaters laid down outwash deposits of sand and gravel as fans, plains, and terraces along meltwater channels. These deposits are recognizable because of their smooth surface, often displaying channel and bar forms. Such deposits are concentrated between Kirkton and Russeldale east of the Lucan Moraine. Lesser

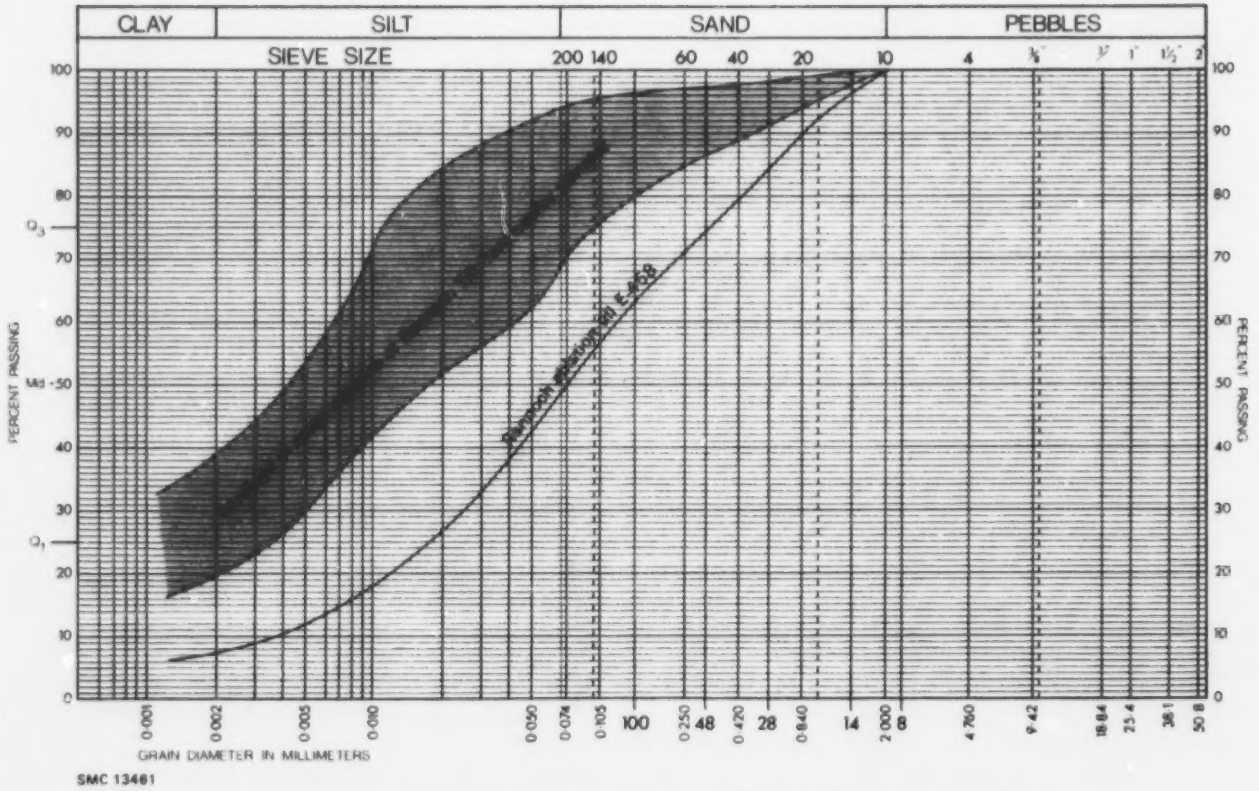
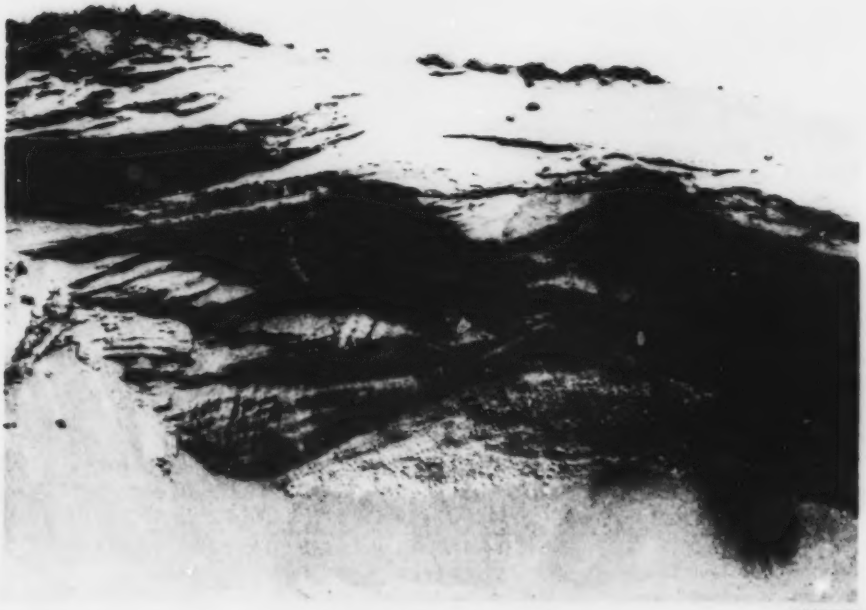



**Figure 7–Cumulative curves for Rannoch ablation till compared to basal till, St. Marys area.**

ODM9545

**Photo 11–Bedding features in Lumley Esker.**



ODM9546

**Photo 12–Bedding features in Lumley Esker.**

deposits occur near St. Marys and east of Exeter. These deposits are exposed in scattered pits but the exposures are usually slumped and reveal little of the internal structure of the deposits. The deposit east of Exeter is an outwash delta and is mainly below the water table. Compared to other areas, outwash deposits in this area are particularly coarse, with average clast size often in the small boulder range.

Outwash bodies are distributed in narrow high terraces along the Avon River and Trout Creek. Much more extensive terrace deposits occur to the south in the Lucan map-area. This area appears to have been one of primarily meltwater erosion, with deposition of coarse sediment of very limited extent. This is probably related to the generally fine texture of the tills and therefore fine texture of the sediment carried by the ice.

The composition of the gravels was determined at 12 sites (Table 6) representing various geological sources of material. Gravel composition parallels that of the tills of the area, reflecting strongly the effect of local limestone bedrock at sites west of the North Thames River (limestone 80-99 percent). Sites to the east have 61-80 percent limestone and 11-25 percent dolomite. Clastic rock types (shale, siltstone, and sandstone), as well as chert, occur only in low percentages throughout the area.

## LACUSTRINE DEPOSITS

Fine-grained sediments, representing deposition in slow-moving or standing water, are widely distributed at the surface in the area. They were laid down either in meltwater lakes and ponds, or as late stages of sedimentation in meltwater channels. The most abundant sediment is silt, but some clay and minor fine sand are included as well. The surface form is level to gently undulating and the distribution is often quite irregular and intricate. Thus, areas shown on Map 2366 (back pocket) as lacustrine often include small areas of till projecting through the silts, and areas mapped as till often include numerous shallow and narrow bodies of silt in depressions in the till surface. These irregular contacts could only be delineated at a mapping scale considerably larger than the present one.

While most of the deposits are relatively thin, only those over three feet (1 m) in thickness are shown in the map. They are seldom exposed other than in ditches, so that the greatest thicknesses are not known. However, thicknesses approaching 10 feet (3 m) would be unusual.

The deposits usually lack any kind of stratification although well-developed lamination was observed at a site four miles (6.4 km) south of Mitchell.

East of the North Thames River and south of the Avon River, the lacustrine sediments grade southward from shallow silts to deeper stony, stiff clay which completely covers the underlying till. This stony clay, which looks very till-like, was ultimately classed as a lacustrine deposit because of its form and distribution. Analyses of this material show an unusually high carbonate ratio (2.3-4.2) unlike the tills of the area, but other properties are similar to clay tills such as the Wartburg Till or the clayey facies of the Rannoch Till.

The prevalence of silt in the lacustrine deposits is probably attributable to the underlying till textures, in which silt is the most abundant component, and the shallowness of the ponded waters, which kept finer sediment in suspension. Presumably some of the clay contributed to the stony clay sediments north of St. Marys, while more was carried into glacial lakes south of the area.

**Table 6** GRAVEL COMPOSITION IN KAME AND OUTWASH DEPOSITS.

| Locality | Deposit | LIMESTONE | DOLOMITE | CHERT | CLASTICS | PRECAMBRIAN |
|---|---|---|---|---|---|---|
| E-25 | burried kame | 80 | 11 | 2 | 4 | 3 |
| E-51 | St. Mary's Esker | 77 | 11 | 1 | 5 | 6 |
| E-71 | Trout Creek terrace | 77 | 15 | 2 | – | 6 |
| E-236 | buried kame, Dublin m. | 91 | 1 | 1 | 2 | 5 |
| E-645 | Kirkton outwash | 92 | 2 | 1 | 2 | 3 |
| S-762 | buried kame | 77 | 11 | 1 | 5 | 6 |
| E-1278 | Avon R. terrace | 62 | 25 | 3 | – | 10 |
| E-1436 | Mitchell Esker | 86 | 3 | 3 | 6 | 2 |
| E-1520 | Staffa kame | 80 | 16 | 2 | – | 2 |
| E-1692 | Lumley Esker | 91 | 5 | 2 | – | 2 |
| E-1775 | Seaforth outwash | 99 | 1 | – | – | – |
| E-1865 | Dublin m. outwash | 91 | 3 | – | 3 | 3 |

## ALLUVIAL DEPOSITS

Young floodplain deposits occur at least sporadically along the margins of most of the streams of the area. Floodplains in the area are generally narrow and in an early stage of geomorphic development. Most streams are near their headwaters and display youthful characteristics. Floodplain deposits are usually thin.

The lithology of the floodplain deposits reflects the nature of the material eroded upstream and at the site. Most deposits are sandy or silty, with gravels occurring sporadically. Gravel is particularly abundant along the larger present streams such as the North Thames River and Avon River. Gravel often represents a lag concentrate of material too coarse to be transported except in times of exceptional floods. Plant remains, logs, and molluscs, sometimes occur in the alluvial deposits.

Older alluvial deposits, intermediate in age between modern floodplains and glaciofluvial outwash terraces, are rare in the area. A small deposit of this type occurs northwest of St. Marys along the North Thames River.

## SWAMP AND BOG DEPOSITS

Although most of the area is of low relief and there are extensive tracts of level and poorly-drained land, accumulation of organic matter in swamps and bogs is extremely limited. This could be related to the highly calcareous nature of the soils of the area, which would contribute to the rapid destruction of organic matter in the alkaline environment.

A very few barely-mappable bodies of peat and muck were located near the east edge of the area and north of Kirkton. In the latter area, fossiliferous marl formed the base of the deposit.

# QUATERNARY HISTORY

## Early and Middle Wisconsinan

The record of events older than Late Wisconsinan is indeed small in the St. Marys area. One or two exposures of contrasting till below Catfish Creek Till comprise the only evidence of older deposits seen during mapping. The best evidence of older deposits comes from the boreholes at the Avonton cut, where interstadial fossiliferous sand and underlying till were encountered below the Catfish Creek Till. Spruce and pine pollen in the sand indicate a cool climate and the probable presence nearby of a forest comparable to the northern Boreal forest of today. These conditions are tentatively considered correlative with those of the Port Talbot Interstade (Dreimanis *et al.* 1966) of about 45,000 years ago, although a Plum Point Interstadial age (about 25,000 years ago) cannot be ruled out. The underlying till is then either of Middle or Early Wisconsinan age, representing a time of general cold climate and glacial cover in southern Ontario. The fossiliferous sediments were deposited either in a pond or in a stream (possibly an

ancestral Avon River) during interstadial and locally non-glacial conditions.

From the study of other areas in southern Ontario, it is known that several major glacial and non-glacial events affected the area in the last 100,000 years (Dreimanis and Karrow 1972). The deposits were either eroded away by later glaciations or were buried. The best part of the area in which to look for such buried deposits is the southeast part, but even there it is known that Catfish Creek Till sometimes rests directly on bedrock with no older deposits preserved. Other possible areas are along buried bedrock valleys, such as east of Exeter and north of Hensall.

## Late Wisconsinan

Almost the entire record of Quaternary time in the area is of Late Wisconsinan age. Some till directly below Catfish Creek Till could represent earliest Late Wisconsinan ice advances, but lacking a clear stratigraphic record, these rare occurrences are assumed to be of greater age.

The first widely-documented event is that of a major ice advance during the Nissouri Stadial over the whole area, which deposited the sandy Catfish Creek Till. Ice moved out of the Huron basin, in contrast to northern or northeastern sources for this till in areas to the east and northeast. An initial northwesterly source is also reported for the Woodstock area by Cowan (1975) with later movements there from the north, northeast and southeast from the Erie basin. Variations of direction with time remain unstudied in the St. Marys area, but some change from early dominance by Huron lobe ice, through regional south or southwesterly flow at the time of maximum ice thickness, and final return to Huron lobe dominance, is to be expected. At maximum thickness and extent, the ice reached southern Ohio 18,000 to 20,000 years ago.

With warming climates glacial retreat uncovered much of southwestern Ontario, with the ice front probably in the northern Huron and eastern Erie basins. In front of the ice in each basin, glacial lakes collected silt and clay and on the land some plant growth occurred. A lake was formed east of St. Marys in which the pollen-bearing Wildwood Silts accumulated. This event is assigned to the time of the Erie Interstade with an age of about 16,000 years.

During the subsequent 2,000 years of the Port Bruce Stadial, a readvance of the ice took place. The ice was apparently unstable during this time and numerous lesser advances and retreats occurred in quick succession laying down a series of till sheets. The earliest, and perhaps most important, is the Tavistock Till, which indicates ice advance of such magnitude that almost all of southern Ontario was again ice-covered. Only a small area northeast of Woodstock was probably not covered by this ice advance (Karrow 1974a; Cowan 1975). Fluctuations of extent during the retreat of this ice gave rise to the Stratford Till, Wartburg Till, and the relatively important Elma Till, all forming till sheets in off-lapping arrangement in the east half of the St. Marys area. Some time during this Stadial, Lake Maumee formed in the Erie basin south of the area, and numerous lesser temporary lakes and ponds were formed within this area.

A significant shift of ice flow from southeast to east is represented by the Rannoch Till, which was deposited by the Huron lobe. During its retreat, with only minor fluctuations, a series of low but prominent end moraines was formed in the western part of the area. Concurrently, meltwaters cut ice-marginal channels and laid down glaciofluvial

gravels in a few places. Continued retreat to well within the Huron basin, and at least to well north of Goderich, is indicated by clay till over sandy till (Catfish Creek Till?) along Boundary Creek, and marks the warmer climates of the Mackinaw Interstade at about 13,300 years ago (Dreimanis and Karrow 1972).

An important glacial readvance during the Port Huron Stadial brought the ice to the Wyoming Moraine, near the west boundary of the area again, about 13,000 years ago. Concurrently a major glacial lake, Lake Whittlesey, was formed in the Erie and Huron basins. The Lake Whittlesey shoreline is found about a mile (1.6 km) west of the area near Centralia.

With the retreat of the ice from the Wyoming Moraine, glaciation ceased to affect the area and postglacial conditions prevailed. An initial tundra vegetation was followed by spruce, pine, and finally hardwood forests, as the climate warmed and conditions like the present evolved (Anderson 1971). Erosion of the terrain by streams dominated, with minor deposition of alluvial sediment along floodplains. In some depressions, slopewash deposition and some accumulation of organic matter took place. An extension of these conditions is continuing today.

## ECONOMIC GEOLOGY

### Sand and gravel

As might be expected from the generally fine texture of the tills of the area, rather little coarse outwash was produced by meltwater streams during glacial retreat. Also, the common presence of pondings and lakes in front of the ice led to some outwash being covered by lacustrine silt and clay.

With rather limited reserves to begin with, the area has never ranked as an important gravel producer. Gravel pits have usually been operated intermittently in response to temporary local demand. As a result, most pits are now inactive and slumped, and good exposures of the material are difficult to find. Many of the deposits are nearly exhausted and at this point probably about half of all the surface gravel deposits have been removed. Thus the future prospect for gravel resources is limited to continued local supplies from fewer districts for some years.

As a corollary to the usual association of coarse outwash with coarse-grained till, it is reasonable to suppose that more substantial outwash deposits were formed during the deposition of the Catfish Creek Till, but would have been buried by the finer tills of later ice advances. Such buried deposits would be hard to find and costly to exploit, but might lend themselves to geophysical prospecting. Buried gravels are being, or have been exploited in or near the area at a few places, and more doubtless occur at undiscovered locations. Till cover in all cases so far is less than 10 feet (3 m). In some cases, association with the Catfish Creek Till is a reasonable assumption, while at others it is an open question.

Buried gravels have been exploited by Yundt Brothers and Jack Tanner in pits about four miles (6.5 km) south of Stratford and along the east edge of the area. A low, gravel-cored ridge trending southwest fades out within a mile (1.6 km); but to the northeast an apparently related knoll, also gravel-cored, is outside the area. The knoll is capped by Stratford and Tavistock Till, while the Tanner pit has a patchy cover of Stratford Till.

These gravels may have a composite origin but seem at least in part to relate to the Catfish Creek Till. The gravels in these pits tend to irregular sorting, texture, and structure, suggesting ice-front deposition. The working faces, 15 to 20 feet (4.6-6.1 m) high, reveal mostly material two to three inches (5.8 cm) in diameter, but bouldery zones are present, as well as silty and sandy zones. A pebble count from this gravel is given in Table 6. A somewhat similar deposit occurs three miles (5 km) north of Stratford; a pebble count from this deposit is given in Table 6.

A small pit in till-capped gravel occurs at the south edge of the area in the Mitchell Moraine. The gravel is medium to coarse, with some small boulders. A till-capped gravel occurs west of Dublin in the front of the Dublin Moraine. The 15-foot (4.6 m) face exposes fine to medium gravel with some large clay ball inclusions near the base. A pebble count on this gravel is given in Table 6.

Buried gravel is exposed in a small pit one mile (1.6 km) southwest of Kirkton. This occurrence is covered by till of the Lucan Moraine. At the contact is a hard cemented gravel layer up to one foot (0.3 m) thick. The proprietor reports gravel at his house which at 20 feet (6 m) provides a good aquifer. The extent of the gravel is not known but the 10-foot (3 m) face exposes medium gravel.

Several pits in the Seaforth Moraine just south of the area exploit buried gravel. Similar buried gravel is indicated in bridge borings along the Little Ausable River at the edge of the Seaforth Moraine three miles (4.8 km) east of Centralia. Association with the Catfish Creek Till is possible as that till is believed to occur at shallow depth in borings near Cromarty and Hensall.

Of the surface gravels, those occurring as eskers will be described first. The largest esker, the St. Marys Esker, is largely worked out. A description of one pit in this esker was given by Hewitt and Karrow (1963) but exposures are now badly slumped. Reference to several pits in this esker was made by Ledoux (1918). A pebble count from this esker is given in Table 6.

Several pits were formerly active in a small esker-outwash deposit west of Stratford (Ledoux 1918) but the deposit is now worked out.

Several eskers are associated with the Rannoch Till. The deposits are quite variable and pits are generally inactive and slumped. Remaining reserves are small. Ledoux (1918) referred to pits near Hensall in these deposits and the present exposures are illustrated in Photos 11 and 12.

Kame deposits are largest near Staffa, with extensive old, slumped workings. The deposits vary from bouldery to sandy. Other kame deposits are rare in the area.

The best quality gravels originate from longer-distance transport by streams, resulting in better sorting and deposition as outwash deposits. Narrow outwash terraces are present sporadically along the Avon River, Trout Creek, and North Thames River valleys, those along the Avon River having been referred to by Ledoux (1918). Most of these deposits are nearly depleted. A pit on the west side of the North Thames River, two miles (3.2 km) northwest of St. Marys exposes gravel in two terrace levels, the higher and older being coarser gravel up to 15 inches (38 cm) in diameter, and the lower and younger terrace being formed by gravel up to six inches (15 cm) in diameter. The effect of greater reworking is obvious here.

Old gravel terraces, partly drowned by Wildwood Lake, are worked in a pit just south of the area. The 15-foot face (4.6 m) revealed poorly sorted gravel up to 24 inches (60 cm) in diameter.

The southeastern part of St. Marys is underlain by good quality gravel. In 1973 a

deep trench revealed 10 feet (3 m) of clean, medium gravel over clay till.

The most important outwash gravels are those associated with meltwater channels in the Kirkton area. A pit at the south edge of Kirkton revealed a 15-foot (4.6 m) sequence of medium to coarse, poorly sorted gravel. A pebble count is recorded in Table 6. Along Flat Creek, and a mile (1.6 km) northeast of Science Hill, a pit has a face up to 20 feet (6.1 m) high of bouldery gravel in which clasts of 15 inches (38 cm) in diameter are common and some up to 24 inches (60 cm) in diameter are present.

A gravel deposit formed a delta in a small glacial lake three miles (4.8 km) southeast of Exeter, and in front of the Seaforth Moraine. A pebble count on the cobbly gravels is given in Table 6. Most of the gravel is below water table and is not well exposed.

As with texture, gravel composition reflects that of the nearby till. Gravels in the area are all predominantly limestone, particularly west of the Mitchell Moraine, where they are associated with the high-limestone Rannoch Till.

High boulder content is a common feature of the gravels of the area, particularly in the western part. The boulders are predominantly limestone and are locally derived. The common occurrence of boulders requires that most gravels be crushed.

## Clay

There are no presently-active clay pits in the area. Clay was formerly exploited for brick manufacture near Mitchell, Dublin and St. Marys (Baker 1906; Keele 1924). The widespread lake deposits of the area suggest that there remain relatively large deposits. However, the siltiness and/or stoniness of most of the deposits suggests they would be of generally poor quality.

## Engineering Geology

Because of the limited urban development and associated construction activity in the area, engineering problems have not been prominent. In fact, rather limited difficulty should be experienced in construction in most parts of the area. The low relief and gentle slopes require only a moderate amount of cut and fill for roads. A few potential problems will be discussed briefly.

Bedrock is generally at such depths that it will seldom be encountered in excavation. Valley sites in the lower North Thames valley and Trout Creek valley are exceptions, as are the areas of shallow drift west of Cromarty. In the latter areas, sinkholes and solution cavities in the limestone bedrock are obvious hazards. There is some evidence that sinkholes are continuing to form at new sites and construction in that district should be preceded by careful study, perhaps including geophysical surveys.

Deep excavation could encounter the Catfish Creek Till, which may be present in the subsurface throughout the area. This material could cause excavation difficulty because of its usual hardness and stoniness. At some sites it has been resistant to ripping and might sometimes be classed as rock for excavation purposes.

Widespread lacustrine silts suggest considerable problems with frost damage on roads other than those built to high standards. High silt content in most of the surface tills could lead to similar problems. A subdivision area near Stratford revealed trafficability

problems in wet conditions on Stratford Till, whereas underlying Tavistock Till remained more firm.

The general lack of permeable materials suggests that water problems, other than surface runoff, should be slight. Intertill sediments, which often supply troublesome water seeps, appear to be relatively uncommon. Substantial water flows are encountered at the base of the gravels in St. Marys and springs are common at the base of the gravels at Staffa. The common occurrence of level, poorly-drained land gives rise to surface water problems, particularly evident in springtime.

# APPENDIX A

## Descriptions of measured sections and borehole logs.

***E-90. South bank, Otter Creek, 1½ mile (2.2 km) north of St. Marys.***

| | | |
|---|---|---|
| 0-0.3 m | 0-1′ | soil. |
| 0.3-2-1 m | 1-7′ | brown, gritty, clayey silt till. Sample A. |
| 2.1-2.4 m | 7-8′ | fine dirty gravel. Water seep. |
| 2.4-3 m | 8-10′ | blocky, clayey silt time. Sample B. |
| 3-5.5 m | 10-18′ | slump. Probably same till, becoming gray, to creek. |

***E-106. West bank North Thames River, three miles (4.8 km) northwest of St. Marys.***

| | | |
|---|---|---|
| 0-0.9 m | 0-3′ | soil and road fill. |
| 0.9-8.2 m | 3-27′ | till. Upper 6′ (2 m) yellow with white carbonate on joints. Silty with grits and pebbles, Sample A at 6′ (2 m). Gradually more brown for next 6′ (2 m) then grading into gray till. Sample B at 25′ (7.5 m). |
| 8.2-15-5 m | 27-51′ | slump to river. |

***E-145. Wall of borrow pit excavation, south side of county road, west side of Black Creek valley, two miles (3.2 km) southeast of Fullarton.***

| | | |
|---|---|---|
| 0-4.6 m | 0-15′ | gritty silt till. Brown. Sample A at 6′ (2 m). |
| 4.6-7.3 m | 15-24′ | blocky, gray, clayey silt till with less stony surface. Sample B at 18′ (5.5 m). Boulder pavement at top contact. Along creek east bank small exposure shows 4′ (1.3 m) buff stony sandy till (Catfish Creek Till). Sample C. |

***E-165. East bank of Black Creek, two miles (3.2 km) southeast of Fullarton.***

| | | |
|---|---|---|
| 0-3.4 m | 0-11′ | medium brown, gritty, clayey silt till. Sample A at 6′ (2 m). |
| 3.4-4 m | 11-13′ | blocky clay till with sparse grits and pebbles. Gray at base. Band of cream silt at base. |
| 4-6.1 m | 13-20′ | gray, clayey to silty clay till with remnant stratification. Grits and pebbles sparse. Sample B at 15′ (4.6 m). |
| 6.1-6.4 m | 20-21′ | dirty, fine to medium gravel, partly cemented. |
| 6.4-7.3 m | 21-24′ | sandy, stony till with many inclusions of vari-textured till. Upper part yellow, lower part gray. Bouldery at base. Sample C at 22′ (6.7 m). Catfish Creek Till. |
| 7.3-7.9 m | 24-26′ | gray, substratified, gritty, silty clay till. |
| 7.9-10.4 m | 26-34′ | slump to creek. 100′ (30 m) north 4 feet (1.3 m) above creek gray clay till with remnant stratification is exposed. Sample D. |

***E-166. East bank of North Thames River, three miles (4.8 km) northwest of St. Marys.***

| | | |
|---|---|---|
| 0-4.3 m | 0-14′ | buff, sandy to silty, stony till. Near base partly cemented. Catfish Creek Till. Sample A at 8′ (2.5 m). |
| 4.3-4.6 m | 14-15′ | stratified sand, silt, and gravel. |
| 4.6-6-7 m | 15-22′ | interbedded medium and coarse sand with sandy till. |
| 6.7-8.2 m | 22-27′ | covered. |
| 8.2-8.5 m | 27-28′ | sandy, silty, stony till. Catfish Creek Till. Sample B. 100′ (30 m) downstream similar till rests on bedrock striated at 130 degrees. 100′ (30 m) up [illegible]am up to 3′ (1 m) exposed of interbedded gray clay, and tilly bands, under sandy till. |

***E-167. East bank of North Thames River, just south of Avon River mouth.***

| | | |
|---|---|---|
| 0-1.2 m | 0-4′ | road fill. |
| 1.2-3.4 m | 4-11′ | light brown to buff silts, occasional pebble. |
| 3.4-4.6 m | 11-15′ | dark gray, gritty silt till. Sample B. |
| 4.6-5.8 m | 15-19′ | covered. |
| 5.8-6.1 m | 19-20′ | similar till. |

| | | |
|---|---|---|
| 6.1-8.8 m | 20-29′ | covered. |
| 8.8-9.7 m | 29-32′ | similar till. |
| 9.7-10.4 m | 32-34′ | covered. |
| 10.4-10.7 m | 34-35′ | transfer section 50′ (15 m) north. Gritty dark gray, slightly clayey silt till. |
| 10.7-11 m | 35-36′ | light gray-buff, sandy silty hard stony till. Catfish Creek Till. Sample A. |
| 11-13.7 m | 36-45′ | covered to river. |

***E-221. New St. Marys Cement quarry, west side North Thames River at St. Marys.***

| | | |
|---|---|---|
| 0-1.5 m | 0-5′ | gritty, clayey silt till. Sample A. |
| 1.5-1.8 m | 5-6′ | stony silt. |
| 1.8-2.4 m | 6-8′ | clay till. Sample B. |
| 2.4-4 m | 8-13′ | stratified clay and silt with till bands. |
| 4-7 m | 13-23′ | stratified sand and gravel, 1-5″ diameter (2.5-12.5 cm). Scattered lenses at base of sandy till up to 1′ (0.3 m) thick. Catfish Creek Till. Sample C. Rests on limestone striated and grooved at 140 degrees. |

***E-315. East bank of North Thames River, two miles (3.2 km) north of Mitchell.***

| | | |
|---|---|---|
| 0-0.6 m | 0-2′ | soil and yellow fine sand. |
| 0.6-3.7 m | 2-12′ | buff to brown silt till low in stones. Sample A at 6′ (2 m). |
| 3.7-5.2 m | 12-17′ | buff, gritty, stony, slightly sandy silt till. Gray at 14′ (4.2 m). Sample B. |
| 5.2-7.3 m | 17-25′ | slump to river. |

***E-317. East bank of North Thames River, 1 mile (1.6 km) southeast of Fullarton. Poorly exposed.***

| | | |
|---|---|---|
| 0-2.4 m | 0-8′ | brown silt till. Sample A at 6′ (2 m). |
| 2.4-5.5 m | 8-18′ | buff, hard, stony, silty sandy till. Catfish Creek Till. Sample at base. |
| 5.5-6.4 m | 18-21′ | slump to river. |

***E-318. North bank of Black Creek near mouth.***

| | | |
|---|---|---|
| 0-1.5 m | 0-5′ | weathered, gravelly, gritty silt till. Sample C. |
| 1.5-2.4 m | 5.8′ | silty to clayey till? |
| 2.4-3.7 m | 8-12′ | silty clay till, low in stones. Sample B. |
| 3.7-4.9 m | 12-16′ | covered. |
| 4.9-6.4 m | 16-21′ | hard, stony, silty sand till. Catfish Creek Till. Sample A. |
| 6.4-12.8 m | 21-42′ | slump to creek. Same sandy till in spotty exposures. |

***E-1854. South bank of Black Creek, 0.6 miles (1 km) southwest of Carlingford.***

| | | |
|---|---|---|
| 0-0.3 m | 0-1′ | soil. |
| 0.3-2.4 m | 1.8′ | gritty, sandy silt till. Sample A. |
| 2.4-6.1 m | 8-20′ | gritty, clayey silt till. Sample B. |
| 6.1-9.5 m | 20-31′ | slump to creek. |

***E-1855. North bank of Black Creek, west of E-1854.***

| | | |
|---|---|---|
| 0-0.3 m | 0-1′ | soil. |
| 0.3-1.2 m | 1-4′ | stony sand. |
| 1.2-7.3 m | 4-24′ | stony, gritty, blocky silt till. |
| 7.3-9.2 m | 24-30′ | slump to creek. |

***E-1856. North bank of Black Creek 1.2 miles (2 km) west of Carlingford.***

| | | |
|---|---|---|
| 0-0.3 m | 0-1′ | soil. |
| 0.3-3.7 m | 1-12′ | sandy, clayey silt till, more clayey downward. Sample A1 near top and A2 near base. |
| 3.7-4.3 m | 12-14′ | yellow silt. |
| 4.3-4.6 m | 14-15′ | clay. |
| 4.6-9.2 m | 15-30′ | silty clay till. Sample B. |
| 9.2-10.0 m | 30-33′ | slump to creek. |

***E-1881. Road cut, east side county road, north side of Otter Creek valley. 1.6 miles (2.6 km) north of St. Marys.***

| | | |
|---|---|---|
| 0-1.2 m | 0-4′ | brown, blocky, stony clay. Till-like. Sample A. |
| 1.2-2.1 m | 4-7′ | buff, stony, sandy, silty till. Stratford Till. Sample B. |
| 2.1-3 m | 7-10′ | brown, gritty, clayey silt till. Tavistock Till. Sample C. |

| | | |
|---|---|---|
| 3-3.4 m | 10-11′ | stratified silt and sand. |
| 3.4-4 m | 11-13′ | yellow sandy till. Catfish Creek Till. Sample D. Cut on west side of road continues lower with finer till at base. Sample E. |

***E-1882 Avonton Cut. Road cuts along county road, east side of Avon River valley 1.6 miles (2.6 km)***

| | | |
|---|---|---|
| 0-0.3 m | 0-1′ | sandy soil. |
| 0.3-0.6 m | 0-2′ | dirty gravel. |
| 0.6-0.9 m | 2-3′ | stratified clay. |
| 0.9-1.5 m | 3-5′ | brown stony clay with few pebbles. Till-like. Sample C. |
| 1.5-3 m | 5-10′ | buff, gritty, stony, silty sand till. Stratford Till. Sample B. |
| 3-3.3 m | 10-11′ | lenses of water-bearing medium sand. |
| 3.3-4.3 m | 11-14′ | gray-brown, blocky silty till. Tavistock Till. Sample A. |

***University of Waterloo BH 3-72 (Avonton cut).***

| | | |
|---|---|---|
| 0-2.3 m | 0-7.5′ | brown, gritty silt till. Sample 1882D at 4′ (1.3 m). |
| 2.3-2.9 m | 7.5-9.5′ | laminated silt. |
| 2.9-4.7 m | 9.5-15.5′ | gray-buff, sandy to silty till, fairly stony. Sample 1882E at 11′ (3.4 m). |
| 4.7-9.1 m | 15.5-30.0′ | gray, gritty, stony, silt till. Sample 1882F at 19′ (5.8 m). Sample 1882G at 28′ (8.5 m). |

***University of Waterloo BH 4-72 (Avonton cut).***

| | | |
|---|---|---|
| 0-0.6 m | 0-2′ | disturbed. |
| 0.6-1.1 m | 2-3.5′ | buff, gritty silt till. |
| 1.1-2.3 m | 3.5-7.5′ | olive, silty to sandy, soft stony till. Sample 1882H at 7′ (2.1 m). |
| 2.3-4.6 m | 7.5-15.0′ | buff, gritty stony, silt till. Sample 1882I at 11′ (3.4 m). |
| 4.6-10 m | 15.0-33.0′ | gray, stony, silty sandy till. Sample 1882J at 19′ (5.8 m). Sample 1882K at 32′ (9.7 m). |
| 10-17.7 m | 33.9-58.5′ | gray, stratified sand and silt with black laminations. Sulphurous smell. Shell fragments. |
| 17.7-19.2 m | 58.5-63.0′ | gray to olive, gritty, stony, sandy, silt till. Sample 1882L at 61′ (18.6 m). |
| 19.2-20 m | 63-65.5′ | dirty gravel. |
| 20-21.4 m | 65.5-70′ | fractured rock, some possible till. Refusal. Sample 1882M at 70′ (21.4 m). |

***University of Waterloo BH 44-74. Sinkhole area 1.4 miles (2.2 km) west of Staffa.***

| | | |
|---|---|---|
| 0-1.3 m | 0-4′ | buff soil and stony silt. |
| 1.3-2.7 m | 4-9′ | brown, clayey silt till. Sample 44-74A at 5′ (1.5 m). |
| 2.7-3.7 m | 9-12′ | gray, sandy silt till. Sample 44-74B at 11′ (3.4 m). |
| 3.7-4.9 m | 12-16′ | buff, hard, stony silt till. |
| 4.9-9.3 m | 16-30.5′ | gray, stony sandy silt till. Sample 44-74C at 19′ (5.8 m). Sample 44-74D at 26′ (7.9 m). |
| 9.3-9.8 m | 30.5-32′ | dense, blocky, silt till. Sample 44-74E at 31′ (9.5 m). |
| 9.8-12.2 m | 32-40′ | gray to buff, banded, stylolitic limestone. |

***St. Marys Cement old quarry, south edge of St. Marys. Clay pit, southwest of old quarry. Measured 1968.***

| | | |
|---|---|---|
| 0-0.3 m | 0-1′ | soil. |
| 0.3-0.9 m | 1-3′ | lens of yellow sandy silt. |
| 0.9-1.7 m | 3-5.5′ | stony clay. |
| 1.7-2.4 m | 5.5-8′ | gritty, sandy silt till. Sample A. |
| 2.4-3 m | 8-10′ | blocky, gritty, clayey silt till. Gray. Sample B. |
| 3-3.7 m | 10-12′ | gray, medium to coarse sand and gravel lens. |
| 3.7-4.0 m | 12-13′ | same gray till. |
| 4-6.1 m | 13-20′ | slump to pit floor. Same till in pit floor but with some remnant stratification and less stony. |

***Quarry section, south face near west end.***

| | | |
|---|---|---|
| 0-0.6 m | 0-2′ | disturbed tilly material. |
| 0.6-1.4 m | 2-4.5′ | interbedded silt with grits and clayey silt with grits and pebbles. |

## St. Marys Area

| | | |
|---|---|---|
| 1.4-1.5 m | 4.5-5′ | fine gravel. |
| 1.5-3.8 m | 5-12.5′ | brown over gray, blocky, gritty, clayey silt till. Sample C. More clayey to base. |
| 3.8-4.7 m | 12.5-15.5′ | gray, stony, silty sand till. Sample D. |
| 4.7-7.6 m | 15.5-25′ | mostly slump, but probably same till. |
| 7.6-10 m | 25-33′ | gray silt. |
| 10-11 m | 33-36′ | dense gray silt till. Sample E. Striae on bedrock at 135 degrees. Farther east good striae at 40 degrees. |

***Lucan sheet. West bank of North Thames River, 0.9 miles (1.5 km) south of Rannoch.***

| | | |
|---|---|---|
| 0-2.1 m | 0-7′ | light brown to buff, sandy silty till. Sample A at 6′ (2 m). |
| 2.1-4 m | 7-13′ | interbedded buff sandy till and fine sand, some silt and clay bands. In part well stratified. |
| 4-4.9 m | 13-16′ | stratified, buff, fine sand and silt. |
| 4.9-7.6 m | 16-25′ | Blocky silt till. Sample B at 22′ (6.7 m). Texture varies from clayey silt, where sampled, to sandy silt. |
| 7.6-15.2 m | 25-50′ | slump to river. |

# APPENDIX B

## ANALYTICAL RESULTS ON TILL SAMPLES.

| Sample No. | Sd | St | Sl | Ca | Dol | Total | Ratio | Ls | Dol | Chert | Clastics | Prec. | Till (3) etc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E–6A | 54 | 33 | 13 | 28 | 29 | 57 | 1.0 | | | | | | S |
| 6B | 29 | 49 | 22 | 20 | 19 | 39 | 1.0 | 61 | 19 | – | 14 | 6 | T |
| 6C | 48 | 37 | 15 | 21 | 26 | 57 | 0.8 | 77 | 13 | – | 3 | 7 | CC |
| 19 | 22 | 48 | 30 | 26 | 19 | 45 | 1.3 | 72 | 16 | 1 | 3 | 8 | S |
| 41 | 20 | 48 | 32 | 23 | 18 | 41 | 1.3 | 74 | 16 | – | 2 | 8 | T |
| 73A | 27 | 48 | 25 | 22 | 21 | 43 | 1.1 | 73 | 11 | 1 | 6 | 9 | T |
| 73B | 41 | 44 | 15 | 27 | 24 | 51 | 1.2 | | | | | | CC |
| 82A | 29 | 42 | 29 | 23 | 19 | 42 | 1.2 | | | | | | T |
| 82B | 30 | 53 | 17 | 24 | 23 | 47 | 1.0 | | | | | | CC |
| 90A | 35 | 38 | 27 | 22 | 18 | 40 | 1.2 | | | | | | ? |
| 90B | 13 | 50 | 37 | 20 | 20 | 40 | 1.0 | | | | | | ? |
| 92 | 7 | 48 | 45 | 26 | 11 | 37 | 2.3 | | | | | | lacustrine |
| 97 | 22 | 50 | 28 | 26 | 17 | 43 | 1.5 | | | | | | T |
| 101 | 31 | 52 | 17 | 25 | 23 | 48 | 1.1 | | | | | | S |
| 106A | 27 | 55 | 18 | 21 | 21 | 42 | 1.0 | | | | | | Rm |
| 106B | 25 | 51 | 24 | 23 | 17 | 40 | 1.3 | | | | | | TL |
| 134A | 30 | 47 | 23 | 32 | 18 | 50 | 1.7 | | | | | | Rm |
| 134B | 24 | 43 | 33 | 28 | 15 | 43 | 1.8 | | | | | | TL |
| 145A | 35 | 42 | 23 | 30 | 23 | 53 | 1.3 | | | | | | Rm |
| 145B | 23 | 43 | 34 | 23 | 17 | 40 | 1.3 | | | | | | TL |
| 145C | 43 | 44 | 13 | 21 | 25 | 46 | 0.8 | | | | | | CC |
| 152 | 24 | 47 | 29 | 23 | 18 | 41 | 1.2 | | | | | | T |
| 162 | 43 | 45 | 12 | 20 | 29 | 49 | 0.7 | | | | | | CC |
| 165A | 31 | 42 | 27 | 25 | 21 | 46 | 1.2 | | | | | | ? |
| 165B | 12 | 55 | 33 | 25 | 16 | 41 | 1.5 | | | | | | ? |
| 165C | 43 | 49 | 8 | 29 | 19 | 48 | 1.6 | | | | | | CC |
| 165D | 10 | 51 | 39 | 22 | 23 | 55 | 0.7 | | | | | | ? |
| 166A | 36 | 50 | 14 | 20 | 24 | 44 | 0.8 | | | | | | CC |
| 166B | 22 | 60 | 18 | 20 | 26 | 46 | 0.8 | | | | | | CC |
| 167A | 36 | 47 | 17 | 25 | 26 | 51 | 1.0 | | | | | | CC |
| 167B | 15 | 47 | 38 | 25 | 17 | 42 | 1.4 | | | | | | Rm |
| E–176 | 3 | 81 | 16 | 19 | 23 | 42 | 0.8 | | | | | | Wildwood Silts |
| 201 | 34 | 45 | 21 | 26 | 25 | 51 | 1.0 | 72 | 10 | – | 15 | 3 | E |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 218 | 14 | 55 | 31 | 23 | 15 | 38 | 1.5 | | | | | | T? |
| 221A | 35 | 46 | 19 | 20 | 21 | 41 | 1.0 | | | | | | Rm? |
| 221B | 16 | 35 | 49 | 24 | 10 | 34 | 2.5 | | | | | | TL? |
| 221C | 50 | 37 | 13 | 25 | 25 | 50 | 1.0 | | | | | | CC |
| 228 | 31 | 44 | 25 | 26 | 23 | 49 | 1.1 | 84 | 12 | 2 | – | 2 | Rm |
| 236 | 18 | 58 | 24 | 28 | 27 | 55 | 1.0 | | | | | | Rd |
| 264 | 20 | 53 | 27 | 30 | 28 | 58 | 1.1 | | | | | | Rs |
| 279 | 22 | 52 | 26 | 31 | 29 | 60 | 1.1 | 94 | 1 | 2 | – | 3 | Rs |
| 309 | 18 | 51 | 31 | 31 | 27 | 58 | 1.1 | | | | | | Rs |
| 315A | 8 | 54 | 38 | 27 | 22 | 49 | 1.2 | | | | | | ? |
| 315B | 32 | 44 | 24 | 28 | 24 | 52 | 1.2 | | | | | | ? |
| 317A | 18 | 56 | 26 | 23 | 21 | 44 | 1.1 | | | | | | ? |
| 317B | 48 | 42 | 10 | 21 | 27 | 48 | 0.8 | | | | | | CC |
| 318A | 54 | 36 | 10 | 21 | 30 | 51 | 0.7 | | | | | | CC |
| 318B | 16 | 37 | 47 | 27 | 16 | 43 | 1.7 | | | | | | ? |
| 318C | 32 | 46 | 22 | 23 | 20 | 43 | 1.2 | | | | | | ? |
| 336 | 16 | 49 | 35 | 39 | 20 | 59 | 2.0 | 92 | 6 | 1 | – | 1 | Rs |
| 341 | 6 | 51 | 43 | 27 | 20 | 47 | 1.4 | | | | | | Rc |
| 354 | 4 | 55 | 41 | 25 | 24 | 49 | 1.0 | | | | | | Rc |
| 365 | 16 | 51 | 33 | 39 | 16 | 55 | 2.4 | | | | | | Rc |
| 374 | 13 | 51 | 36 | 34 | 19 | 53 | 1.8 | 95 | 2 | – | – | 3 | Rc |
| 414 | 11 | 51 | 38 | 30 | 21 | 51 | 1.5 | 94 | 1 | – | – | 5 | R1 |
| 442 | 6 | 55 | 39 | 31 | 22 | 53 | 1.4 | | | | | | Rm |
| 449 | 20 | 47 | 33 | 30 | 18 | 48 | 1.7 | | | | | | Rm |
| 458 | 53 | 39 | 8 | 25 | 24 | 49 | 1.1 | | | | | | Rm (ablation) |
| 462 | 19 | 47 | 34 | 28 | 19 | 47 | 1.5 | 94 | 1 | – | 1 | 4 | Rm |
| 478 | 38 | 43 | 19 | 23 | 22 | 45 | 1.0 | 82 | 4 | – | 2 | 12 | S |
| 502 | 33 | 45 | 22 | 23 | 22 | 45 | 1.0 | | | | | | Rm |
| E–513 | 36 | 48 | 16 | 21 | 23 | 47 | 0.8 | 60 | 24 | 3 | 1 | 12 | CC |
| 522 | 24 | 59 | 27 | 30 | 21 | 51 | 1.4 | | | | | | Rm |
| 559 | 8 | 55 | 37 | 29 | 12 | 41 | 2.5 | | | | | | Rs |
| 602 | 24 | 53 | 23 | 32 | 25 | 57 | 1.3 | | | | | | Rm |
| 706A | 15 | 48 | 34 | 23 | 22 | 45 | 1.1 | | | | | | E? |
| 706B | 3 | 24 | 73 | 26 | 8 | 34 | 3.3 | | | | | | W? |
| 707 | 13 | 61 | 26 | 21 | 27 | 48 | 0.8 | | | | | | E |
| 1030 | 17 | 55 | 28 | 21 | 31 | 52 | 0.7 | 64 | 26 | 4 | – | 6 | E |
| 1046 | 7 | 37 | 56 | 20 | 15 | 35 | 1.4 | | | | | | W |
| 1058 | 39 | 37 | 24 | 25 | 23 | 48 | 1.1 | | | | | | S |
| 1081 | 13 | 46 | 41 | 26 | 21 | 47 | 1.2 | 67 | 15 | 2 | 6 | 10 | W |

(continued)

Appendix B (continued)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1083 | 8 | 38 | 54 | 28 | 14 | 42 | 2.0 | | | | | W |
| 1104 | 12 | 53 | 35 | 18 | 21 | 39 | 0.9 | | | | | E |
| 1123 | 20 | 53 | 27 | 25 | 29 | 54 | 0.8 | | | | | S |
| 1142 | 31 | 42 | 27 | 26 | 21 | 47 | 1.3 | 73 | 18 | 2 | 1 | 6 E |
| 1227 | 6 | 54 | 40 | 25 | 22 | 47 | 1.2 | | | | | W |
| 1231 | 10 | 56 | 34 | 24 | 22 | 46 | 1.1 | | | | | T |
| 1235 | 20 | 46 | 34 | 23 | 16 | 39 | 1.4 | | | | | S? |
| 1243 | 32 | 49 | 19 | 20 | 25 | 45 | 0.8 | | | | | S? |
| 1257 | 23 | 44 | 33 | 33 | 17 | 50 | 1.9 | 73 | 16 | 2 | 3 | 6 lacustrine |
| 1300 | 10 | 46 | 44 | 35 | 14 | 49 | 2.5 | | | | | ? |
| 1307A | 26 | 52 | 22 | 29 | 29 | 58 | 1.0 | | | | | ? |
| 1307B | 23 | 39 | 38 | 23 | 17 | 40 | 1.3 | | | | | Rm |
| 1353 | 14 | 54 | 32 | 29 | 21 | 50 | 1.4 | 81 | 7 | – | 4 | 8 Rm |
| 1358 | 26 | 44 | 30 | 24 | 19 | 43 | 1.2 | | | | | E |
| 1394 | 9 | 53 | 38 | 26 | 25 | 51 | 1.0 | | | | | E |
| 1396 | 35 | 41 | 24 | 20 | 23 | 43 | 0.9 | | | | | Rm |
| 1408 | 28 | 39 | 33 | 25 | 19 | 44 | 1.3 | | | | | Rm |
| 1410 | 11 | 56 | 33 | 27 | 24 | 51 | 1.1 | | | | | Rm |
| 1425 | 24 | 43 | 33 | 23 | 20 | 43 | 1.1 | | | | | Rm |
| E–1429 | 17 | 39 | 44 | 23 | 17 | 40 | 1.4 | | | | | Rm |
| 1464 | 23 | 44 | 33 | 21 | 24 | 45 | 0.9 | | | | | Rd |
| 1510 | 19 | 56 | 25 | 28 | 28 | 56 | 1.0 | 89 | 2 | – | 8 | 1 ? |
| 1533A | 25 | 51 | 24 | 20 | 22 | 42 | 0.9 | | | | | ? |
| 1533B | 8 | 60 | 32 | 21 | 19 | 40 | 1.1 | | | | | Rd |
| 1567 | 22 | 55 | 23 | 32 | 28 | 60 | 1.1 | | | | | Rl |
| 1584 | 26 | 55 | 19 | 31 | 30 | 61 | 1.0 | | | | | Rl |
| 1696 | 20 | 51 | 29 | 26 | 28 | 54 | 0.9 | 92 | 4 | 1 | – | 3 Rs |
| 1702 | 3 | 50 | 47 | 35 | 16 | 51 | 2.3 | | | | | Rl |
| 1743 | 16 | 46 | 38 | 25 | 24 | 49 | 1.0 | | | | | Rm |
| 1831 | 13 | 45 | 42 | 24 | 21 | 45 | 1.1 | | | | | Rl |
| 1837 | 11 | 51 | 38 | 28 | 25 | 53 | 1.1 | | | | | ? |
| 1854A | 23 | 41 | 36 | 30 | 15 | 45 | 2.0 | | | | | ? |
| 1854B | 29 | 30 | 41 | 26 | 15 | 41 | 1.7 | | | | | ? |
| 1856A1 | 32 | 41 | 27 | 22 | 21 | 53 | 1.0 | | | | | ? |
| 1856A2 | 21 | 42 | 37 | 26 | 16 | 42 | 1.6 | | | | | ? |
| 1856B | 8 | 33 | 59 | 29 | 11 | 40 | 2.8 | | | | | Rl |
| 1878 | 10 | 53 | 37 | 31 | 21 | 52 | 1.5 | | | | | Rd |
| 1879 | 22 | 42 | 36 | 21 | 21 | 42 | 1.0 | | | | | Rl |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1880 | 10 | 50 | 40 | 30 | 23 | 53 | 1.3 | 94 | 3 | – | – | 3 | lacustrine |
| 1881A | 3 | 28 | 69 | 30 | 7 | 37 | 4.2 | | | | | | S |
| 1881B | 53 | 38 | 9 | 28 | 21 | 49 | 1.3 | | | | | | T |
| 1881C | 10 | 56 | 34 | 25 | 15 | 40 | 1.6 | | | | | | CC |
| 1881D | 34 | 54 | 12 | 21 | 25 | 46 | 0.8 | | | | | | CC? |
| 1881E | 32 | 48 | 20 | 24 | 21 | 45 | 1.2 | | | | | | T |
| 1882A | 24 | 47 | 29 | 20 | 19 | 39 | 1.0 | | | | | | S |
| 1882B | 44 | 42 | 14 | 27 | 26 | 53 | 1.0 | | | | | | lacustrine |
| 1882C | 8 | 25 | 67 | 26 | 8 | 34 | 3.5 | | | | | | T |
| 1882D | 25 | 51 | 24 | 22 | 21 | 43 | 1.0 | | | | | | CC |
| 1882E | 36 | 52 | 12 | 19 | 30 | 49 | 0.7 | | | | | | ? |
| E–1882F | 30 | 55 | 15 | 19 | 18 | 37 | 1.0 | | | | | | ? |
| 1882G | 28 | 58 | 14 | 19 | 25 | 44 | 0.8 | | | | | | CC? |
| 1882H | 25 | 63 | 12 | 16 | 20 | 36 | 0.8 | | | | | | CC? |
| 1882I | 28 | 55 | 17 | 18 | 24 | 42 | 0.8 | | | | | | CC? |
| 1882J | 37 | 52 | 11 | 14 | 24 | 38 | 0.6 | | | | | | CC? |
| 1882K | 25 | 62 | 13 | 18 | 20 | 38 | 0.9 | | | | | | pCC |
| 1882L | 41 | 48 | 11 | 35 | 38 | 73 | 0.9 | | | | | | pCC |
| 1882M | 33 | 57 | 10 | 10 | 16 | 26 | 0.6 | | | | | | Rd |
| BH44-74A | 19 | 53 | 28 | 32 | 25 | 57 | 1.3 | | | | | | CC |
| 44-7HB | 33 | 49 | 16 | 24 | 28 | 52 | 0.9 | | | | | | till-lacustrine |
| 44-74C | 25 | 54 | 21 | 29 | 23 | 52 | 1.3 | | | | | | CC |
| 44-74D | 32 | 52 | 16 | 18 | 37 | 55 | 0.5 | | | | | | pCC |
| 44-74E | 16 | 56 | 28 | 27 | 26 | 53 | 1.0 | | | | | | S? |
| Old Quarry A | 35 | 42 | 23 | 29 | 18 | 47 | 1.6 | | | | | | T |
| B | 38 | 51 | 11 | 21 | 26 | 47 | 0.8 | | | | | | pCC |
| C | 20 | 56 | 24 | 24 | 18 | 42 | 1.3 | | | | | | T |
| D | 25 | 48 | 27 | 22 | 18 | 40 | 1.2 | | | | | | CC |
| E | 7 | 72 | 21 | 24 | 22 | 46 | 1.1 | | | | | | |
| Rannoch A | 32 | 53 | 15 | 20 | 26 | 46 | 0.8 | | | | | | ? |
| B | 18 | 53 | 29 | 21 | 22 | 43 | 1.0 | | | | | | ? |

Notes: (1) Sand >0.062mm, clay <0.002 mm. Percentage of <10 mesh material.
(2) determined on <200 mesh material.
(3) Till abbreviations.
CC–Catfish Creek Till
pCC–pre-Catfish Creek Till
T–Tavistock Till
S–Stratford Till
W–Wartburg Till

TL–Thames valley lower till
E–Elma Till
R–Rannoch Till– Rm–Mitchell tract
Rd–Dublin tract
Rl–Lucan tract
Rs–Seaforth tract
Rc–Centralia tract

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